EMMA AND

CHRISTOPHER LAKES

1981-82

WATER

QUALITY

ASSESSMENT

M·R·2 CONSULTING ENGINEERS

EMMA

and

CHRISTOPHER

LAKES

1981-1982

WATER QUALITY

ASSESSMENT

Prepared for

WATER POLLUTION CONTROL BRANCH

SASKATCHEWAN ENVIRONMENT

by

R.A. McDonald, P.Eng.

M·R·2 CONSULTING ENGINEERS

MARCH 1983

TABLE OF CONTENTS

		Page No.
.	SUMMARY	1
i.	INTRODUCTION	3
	1.1 Background	3
	1.1.1 Setting	3
	1.1.2 Water Quality Surveillance	5
	1.2 Purpose and Scope	5
	1.3 Methodology	6
2.	WATER QUALITY DATA ANALYSIS	7
	2.1 General Water Quality	8
	2.1.1 Diurnal Data	8
	2.1.2 Daiiy Data	23
	2.1.3 Sediments	28
	2.2 Dissolved Oxygen	29
	2.3 Heavy Metals	32
	2.3.1 Water	32
	2.3.2 Sediments	32
	2.3.3 Fish	33
	2.4 Aquatic Biology	34
	2.4.1 Bacteriology	34
	2.4.2 Algae (Phytoplankton)	36
	2.4.3 Aquatic Plants (Macrophytes)	38
	2.4.4 Bottom Living Organisms(Benthos)	38
3.	ASSESSMENT AND RECOMMENDATIONS	41
	3.1 Water Use	41
	3.1.1 Emma Lake	41
	3.1.2 Christopher Lake	41
	3.2 Impact on Uses	41
	3.2.1 Potable Use	41
	3.2.2 Non-potable Domestic Use	42
	3.2.3 Contact Recreation	42
	3.2.4 Non Contact Recreation	42
	3.2.5 Fishing	43

	Page No.
3.2.6 Aquatic Ecology	43
3.3 Other Water Quality Considerations	47
3.4 Water Quality Surveillance	50
ACKNOWLEDGEMENTS	52
REFERENCES	53
APPENDICES	55

LIST OF TABLES

		Page No.
2.1	Emma & Christopher Lakes, 1981-82 Sampling Stations	7
2.2	Emma & Christopher Lakes, Diurnal Data--Relative Variations	22
2.3	Analysis of Variance--Stations-Seasons	24
2.4	Analysis of Variance--Mid-lake-Shoreline Stations	25
2.5	Emma Lake--Open Water and Ice Cover--Median Levels	26
2.6	Christopher Lake--Open Water and Ice Cover--Median Levels	27
2.7	Emma & Christopher Lakes--Sediments-General Quality	28
2.8	Emma & Christopher Lakes--Sediments-Heavy Metals-August 1981	33
2.9	Emma & Christopher Lakes--Heavy Metals-Fish	34
2.10	Emma & Christopher Lakes--Bacteriological Quality	35
2.11	Plankton Summary--Types, Species, Cell/Colony Counts	37
2.12	Aquatic Plant Summary	39
3.1	Emma & Christopher Lakes, Calculated Un-ionized Ammonia Levels	45

LIST OF FIGURES

		Page No.
2.1	Key map of Emma & Christopher Lakes showing Cross Section & Station Locations	Following 7
2.2	Total Kjeldahl Nitrogen, Diurnal Trends, August 1981	10
2.3	Total Kjeldahl Nitrogen, Diurnal Trends, October 1981	11
2.4	Total Kjeldahl Nitrogen, Diurnal Trends, May 1982	12
2.5	Total Phosphorus, Diurnal Trends, August 1981	13
2.6	Total Phosphorus, Diurnal Trends, May 1982	14
2.7	Specific Conductance, Diurnal Trends, August 1981	15
2.8	Specific Conductance, Diurnal Trends, October 1981	16
2.9	Specific Conductance, Diurnal Trends, May 1982	17
2.10	Chloride, Diurnal Trends, August 1981	19
2.11	Chloride, Diurnal Trends, October 1981	20
2.12	Chloride, Diurnal Trends, May 1982	21
2.13	Dissolved Oxygen, Diurnal Trends	30

SUMMARY

During 1981-82 the Water Pollution Control Branch, Saskatchewan Environment, undertook, through a consultant, a water quality surveillance program on Emma and Christopher Lakes. These neighboring lakes, located about 45 km north of Prince Albert are two popular, high recreational-use water bodies.

The program, intended to provide a basic insight into the lakes' water quality over the four seasons, encompassed an examination of water, sediment, algae, aquatic plants, and fish. Sampling was carried out on diurnal and on three-consecutive-day bases at a number of sites on the lakes during August 1981, October 1981, February 1982, and May 1982. The data from the monitoring program was collated in a field study report.

This report reviews and analyzes the information obtained during the 1981-82 field study and assesses the seasonal, temporal, and spatial water quality characteristics, comments on the aquatic biology, and identifies major water user and water quality related concerns. Where appropriate and possible, the data was summarized by graphs, tabulations, or statistical analyses.

Overall, the water quality of the lakes can be considered reasonably satisfactory. The lakes may be classed as moderately eutrophic (fertile) based on the aquatic biological growths and water quality data. Blue-green algae predominated in the summer, but it is believed their density was below that encountered under nuisance conditions. Nutrients are available, but phosphorus levels tended to be low.

Variations in certain water quality variables were noted during the diurnal and seasonal periods. Phosphorus particularly fluctuated during measurements at four-hour intervals over a 24-hour period. As expected, concentrations of many variables showed increases during ice cover

conditions compared with open water. Some of the heavy metals, cadmium, chromium, and zinc, were found to have ice cover concentrations in excess of some water quality objectives although oniy a single set of samples was collected.

For the identified uses, the findings had varying degrees of impacts. The waters would basically be suitable for domestic use during the summer although for consumption, treatment by filtration and disinfection should be practised. The presence of cadmium and chromium concentrations in excess of maximum acceptable objectives, in the winter, renders the water unsatisfactory for consumption. These values should be checked by additional sampling.

Based on limited bacteriological data, and other information, the waters would be satisfactory for contact recreation such as swimming. A major concern was manifested from the fish tissue analyses, which detected high levels of mercury in populations of sport fish from both lakes. These levels exceed the guideline for consumption and advisory action respecting the limiting of fish consumption plus further surveillance is recommended.

Dissolved oxygen levels in the lakes were generally satisfactory for the preservation of aquatic life except for the North Emma basin where winter-time levels were extremely low. It was also noted that in the deeper areas, oxygen concentrations tended to be substantially depressed near the bottom during the summer and winter periods. Un-ionized ammonia levels appear to be in excess of criteria for the protection of some fish. It is unknown if toxicity has been observed with the indigenous fish of these lakes, but the question warrants further evaluation.

Included in the observations on the water quality surveillance program was a recommendation that a similar program be undertaken within 5 to 8 years in order to assess trends and possible deterioration.

1. INTRODUCTION

1.1 Background

1.1.1 Setting

Emma and Christopher Lakes are two popular and high-use recreational lakes, located in central Saskatchewan about 45 kilometres north of Prince Albert. Studies on the lakes and surrounding area with respect to uses and development have been carried out by Ecologistics Limited (1976) and the UMA Group (1981) (1) (2).

A summary description of the lakes and their setting has been provided by Integrated Environmental Sciences Inc. (3). The following are excerpts from that description.

Emma Lake consists of a series of three jointed lakes (north, middle, and south Emma Lake). These three lakes and Christopher Lake are kettle lakes which were formed at the end of the last glaciation. They can generally be described as saucer-shaped, consisting of shallow shoreline areas that slope to a deeper central location. The following table provides some basic lake measurements.

	Surface Area (Ha)	Shoreline Length (km)	Maximum Depth (m)
North Emma	970	28	4.0
Middle Emma	240	8.8	8.0
South Emma	650	12.8	10.0
Emma Lake Total	1860	49.6	10.0
Christopher Lake	710	13.4	11.0

The area surrounding Emma and Christopher Lakes is almost entirely forested with the exception of some lands which have been cleared for agriculture.

Emma and Christopher Lakes make up part of the Spruce River Drainage System which flows into the North Saskatchewan River. Both Emma and Christopher Lakes are controlled water level lakes. Water enters north Emma Lake via the Anglin-Emma Water Diversion Canal from the Spruce River Reservoir. It flows into Christopher Lake through a drainage ditch with control valve from South Emma Lake near Neis Beach. Minor contributions are made to the water volumes of Emma and Christopher Lakes from several small lakes and swampy areas adjacent to the two lakes.

Hydrological studies, undertaken by the Hydrology Branch, recommended that lake levels be controlled for Emma Lake at an operating range of 513.9 to 514.22 metres and for Christopher Lake between 513.15 and 513.3 metres. (4)

Emma and Christopher Lakes are located within the Central Lowlands physiographic area, a part of the Saskatchewan Plains Region. The physiography can be generally described as gently to moderately rolling. The region consists of a series of undulating moraine with distinct knob and kettle features of a glacial till plain.

Geologically, the surrounding region within which the lakes are located consists of a surface layer of undifferentiated glacial drift of the Pleistocene Age. This is underlain by Cretaceous bedrock of the Ashvill Lower Colorado group and the Swan River sediment from the Paleozoic Era. It is reported by Kupsch that the surface till was deposited by the last Wisconsin glaciation ending about 12,000 years ago. (5) Anderson and Ellis report that surface materials of recent age are mainly organic peat deposits occuring in poorly drained depressional areas. (6)

1.1.2 Water Quality Surveillance

Water quality monitoring and analyses have been carried out periodically in recent years as part of Saskatchewan Environment's water quality monitoring program. With considerable public and user interest in the lakes' water quality and recognition that a more comprehensive surveillance program was required, the Department, through the Water Pollution Control Branch, designed and commissioned a monitoring program to be undertaken during 1981-82.

It is understood the primary purposes for obtaining the water quality and related data included:

- to provide or allow a statement on water quality as measured during the period.
- to provide a base for a comparison with any subsequent studies.
- to identify unusual observances or significant problems.

The study program and the field program results are well documented in the November 1982 report by Integrated Environmental Sciences Inc. (3) However the data were not interpreted nor assessed in terms of users or problems.

1.2 Purpose and Scope

In the latter part of February 1983, M·R·2 Consulting Engineers was engaged by Saskatchewan Environment to review and analyze the information obtained during the 1981-82 field study with emphasis on:

- the seasonal, temporal and spatial water quality characteristics of the lakes,
- the characteristics of the lakes pertaining to aquatic plants and algae, benthis invertebrates

and sediment chemistry,

. the heavy metal content of game fish,

. the major water user and water quality-related concerns that may be identified.

1.3 Methodology

The data lease used for this review is that covered by the study and report of Integrated Environmental Sciences Inc. (3) Most of the water quality data was placed on the Esquadat system operated by the Water Pollution Control Branch.

Computer generated data and statistical calculations were used extensively in this assessment. Branch staff contributed significantly in the provision of this data.

Basically, the approach used consisted of reviewing the data, defining, and undertaking suitable and applicable data manipulation and display methods, and collection of additional information as required. Some additional discussion in the statistical methods used is appended.

An extensive literature review was not undertaken since it was considered beyond the scope of this assessment.

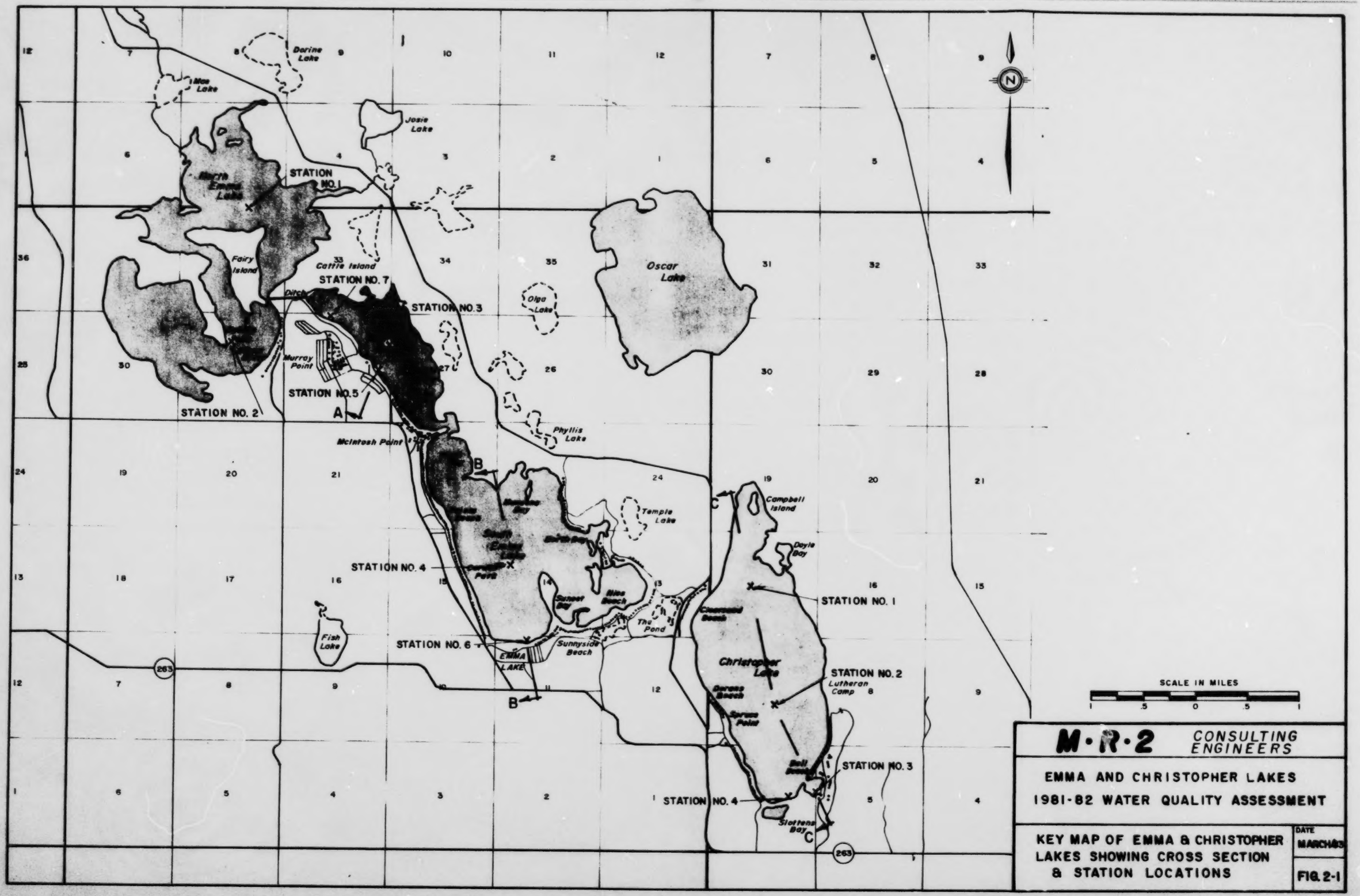
2. WATER QUALITY DATA ANALYSIS

The study program, detailed in the data report, basically consisted of sampling on a seasonal basis (August/81, October/81, February/82, and May/82). The frequency varied from approximately four-hour intervals in the 25-hour diurnal program to a single set of samples. The variables or constituents that were sampled and measured also varied. More specific descriptions are contained in the following sections.

The sites for the sampling stations used on both Emma and Christopher Lakes are noted on Figure 2.1. Table 2.1 summarizes the station numerical designations, their location, and the Esquadat name. Station numbers have been frequently used in this report.

TABLE 2.1
EMMA AND CHRISTOPHER LAKES
1981-82 SAMPLING STATIONS

LAKE	NO	NAME	TYPE OF STATION
EMMA (N)	1	North of Fairy Island Mid-lake	mid-lake
EMMA (N)	2	Mid-lake opposite Okema Beach	mid-lake
EMMA (M)	3	Mid-lake opposite Murray Point	mid-lake
EMMA (S)	4	Mid-lake west of North Bay	mid-lake
EMMA (M)	5	Murray Point off boat launch pier	beach
EMMA (S)	6	Offbeach at Emma Lake subdivision	beach
EMMA (M)	7	Offbeach halfway between Murray Point subdivision and excav.	control
CHRISTOPHER	1	W.S.W. of Doyle Bay mid-lake	mid-lake
CHRISTOPHER	2	Opposite Spruce Point mid-lake	mid-lake
CHRISTOPHER	3	South side of pier at Ball's Beach	beach
CHRISTOPHER	4	In Slottens Bay	control



M·R·2 CONSULTING ENGINEERS

EMMA AND CHRISTOPHER LAKES
1981-82 WATER QUALITY ASSESSMENT

KEY MAP OF EMMA & CHRISTOPHER LAKES SHOWING CROSS SECTION & STATION LOCATIONS

DATE MARCH 83

FIG. 2-1

2.1 General Water Quality

For the purposes of this section, general water quality refers to the organic and inorganic chemical variables (excluding the heavy metals) that were included in the surveillance program.

2.1.1 Diurnal Data

The diurnal monitoring program, for open water conditions only, generally consisted of sample collection at approximately four-hour intervals from most of the stations. Exceptions included nighttime sampling on north Emma and the controls. Samples were normally composited from near surface, mid-depth, and near bottom subsamples. At shallow sites, a mid-depth sample was omitted. The analyses primarily consisted of the variables:

- total kjeldahl nitrogen
- total phosphorus
- specific conductance
- pH (lab)
- chloride
- biochemical oxygen demand

The pH (Laboratory) of the diurnal samples was observed to be quite constant over the periods of measurement.

For Emma Lake the maximum fluctuation was 0.3 units at one station but most of the data indicate a 0.1 unit change. The pH range for all diurnal samples for all open water periods was only 8.4 to 8.8 units. It is noted that field measurements using a colour comparator kit were all recorded at 9.0 units. Christopher Lake also showed minimal fluctuations with a maximum of 0.2 units at one station. The total period range was 8.9 to 9.1 units, slightly higher than for Emma Lake. The field pH observations were also noted, at 9.0 units.

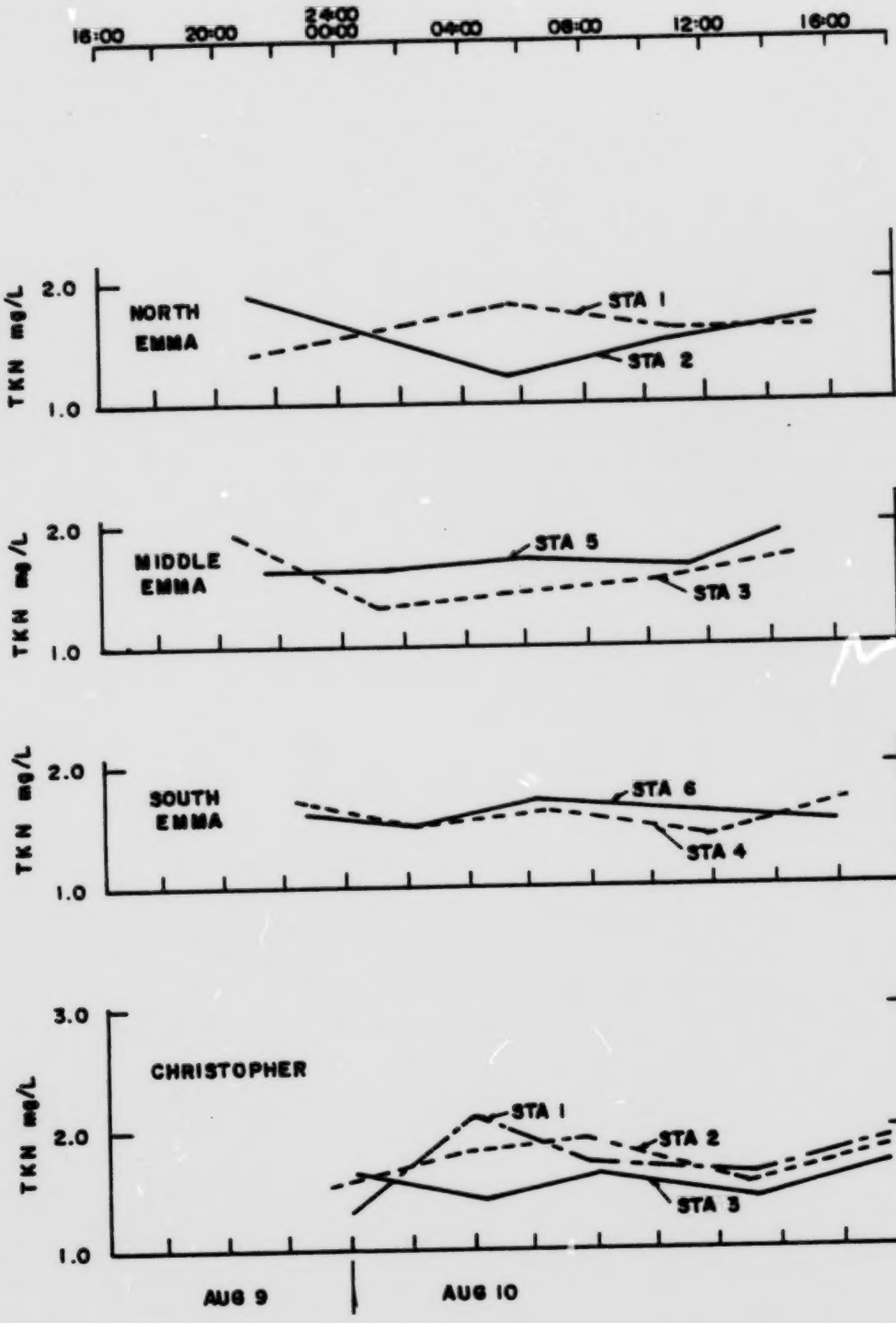
Biochemical oxygen demand was found to be at low levels, such that the analytical significance is questionable. Virtually all of the diurnal samples were reported at less than one mg/L. The highest demand recorded was 2 mg/L.

The other four variables or parameters provided much more interesting cases. The data were examined by preparing graphical plots and also by basic statistical analyses.

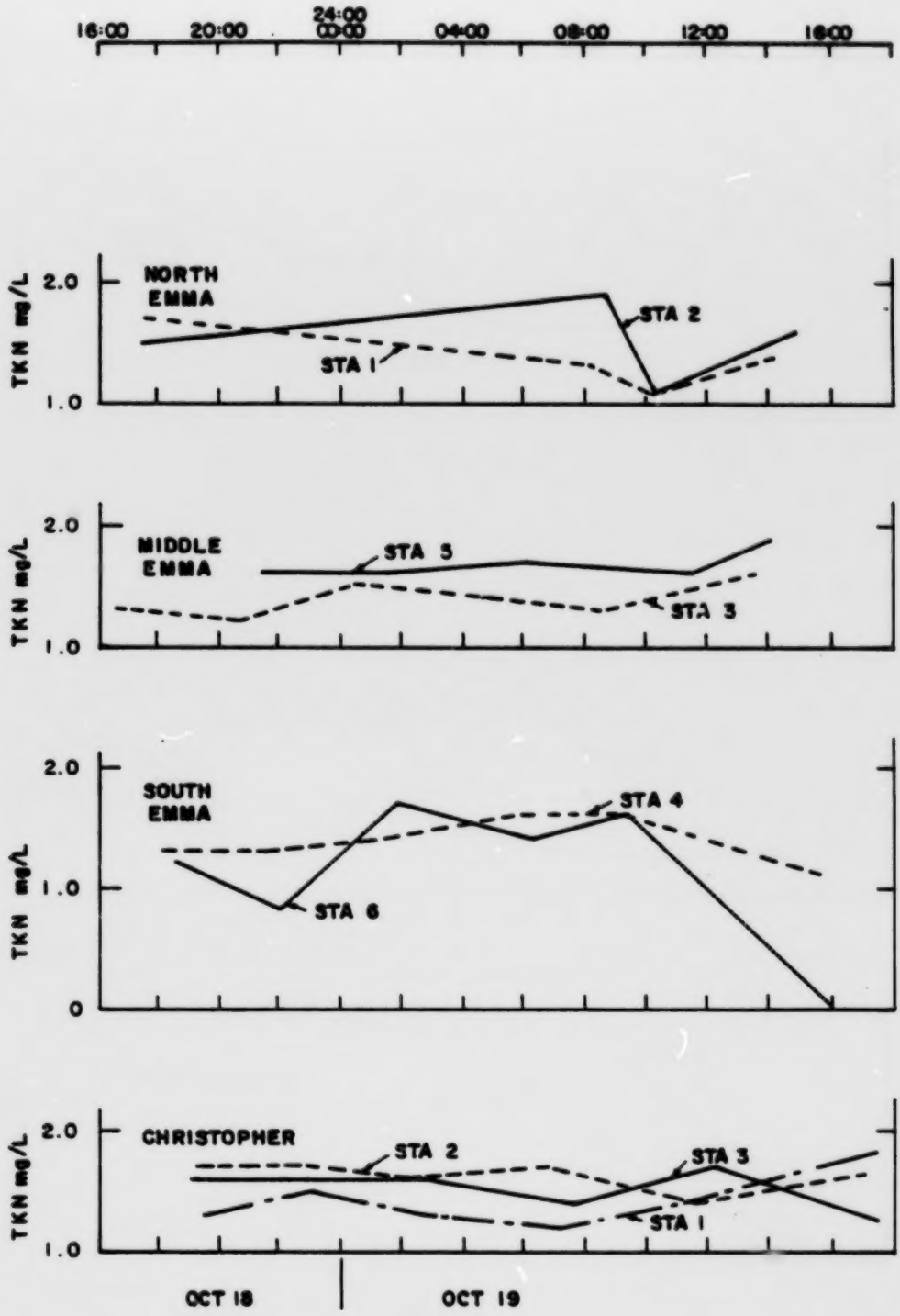
Figures 2.2, 2.3, and 2.4 show the diurnal trends for total kjeldahl nitrogen for the August, October, and May sampling periods. During the summer and fall, the levels tended to be reasonably consistent between 1 and 2 mg/L. The May (spring) values fluctuated considerably more with values of 3 mg/L being observed. The timing of the higher levels was not uniform.

Total phosphorus exhibited much more dramatic variations except for the October/81 set of data. In the fall the concentrations were observed to be quite low generally--in the order of 0.01 mg/L for both lakes. As noted on Figures 2.5 and 2.6, which indicate the August and May total phosphorus trends respectively, there are both high values and considerable changes in levels during the 24-hour period. Substantial peaks were observed during May 1982 in the Middle and South Emma Lake mid-lake stations and at a mid-lake station in Christopher Lake. August 1981 samples also produced peaks but of lesser magnitude. Except for the South Emma beach station, the higher values tended to occur during the nocturnal or very early morning hours. Mid-day peaks occurred at the beach station.

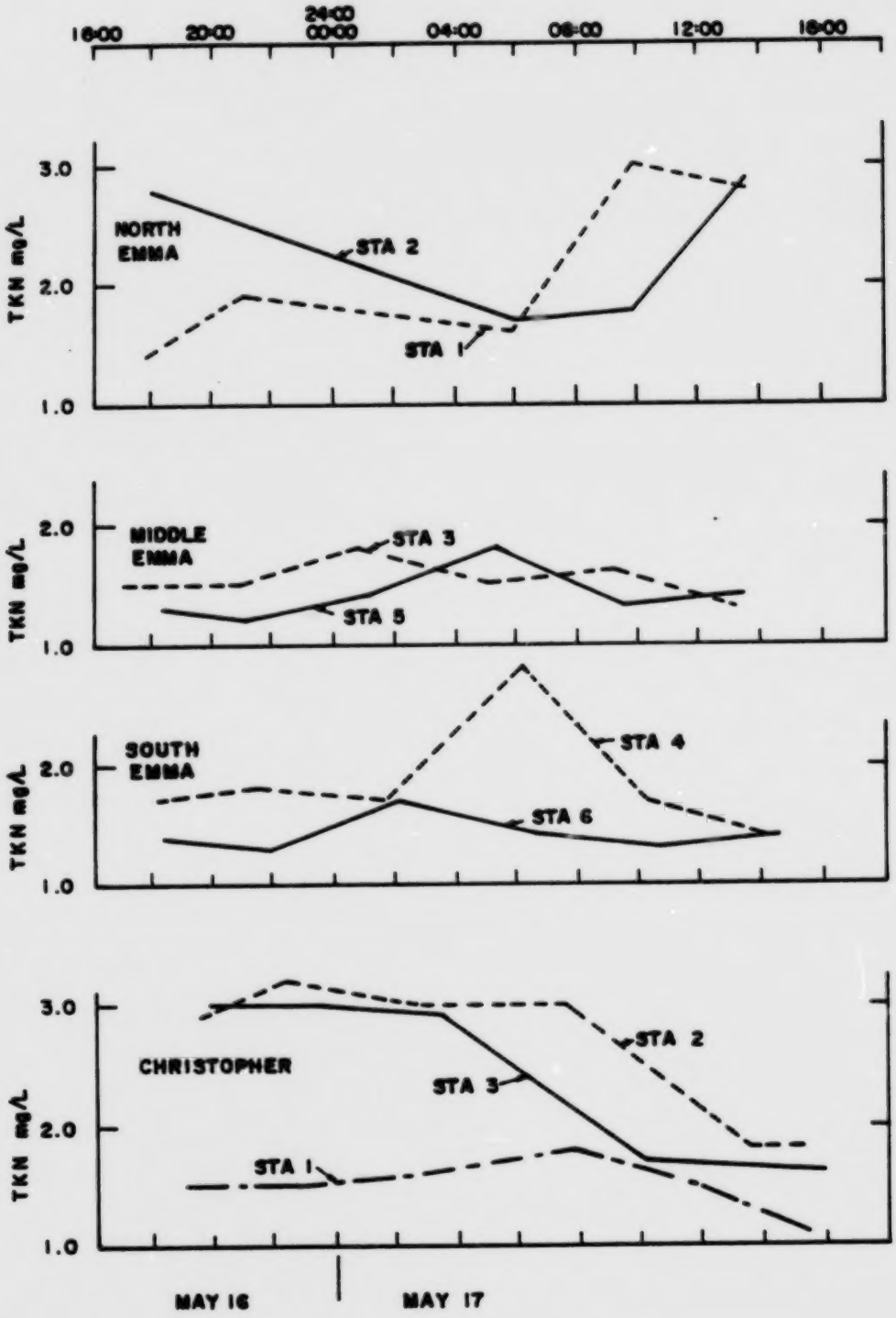
Specific conductance, a measure of dissolved salts, would normally be expected to be reasonably constant over a 24-hour period. in fact, the major changes in a large water body could often be attributed to measurement error. The plots of the diurnal data are shown on Figures 2.7, 2.8, and 2.9. It is noted that for the August 1981 and October 1981 monitoring



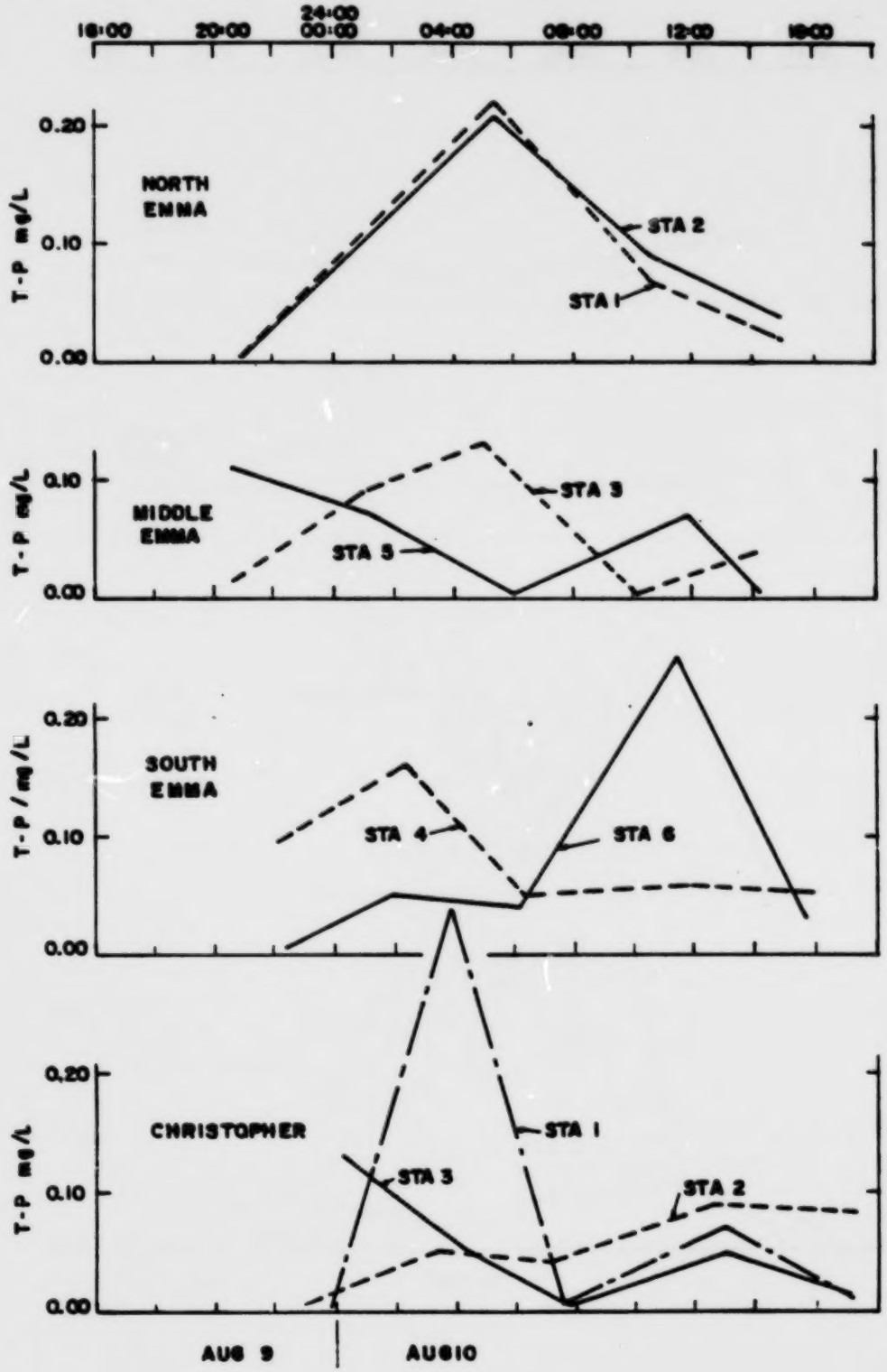
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL KJELDAHL NITROGEN - DIURNAL TRENDS - AUG/81		FIG.2-2



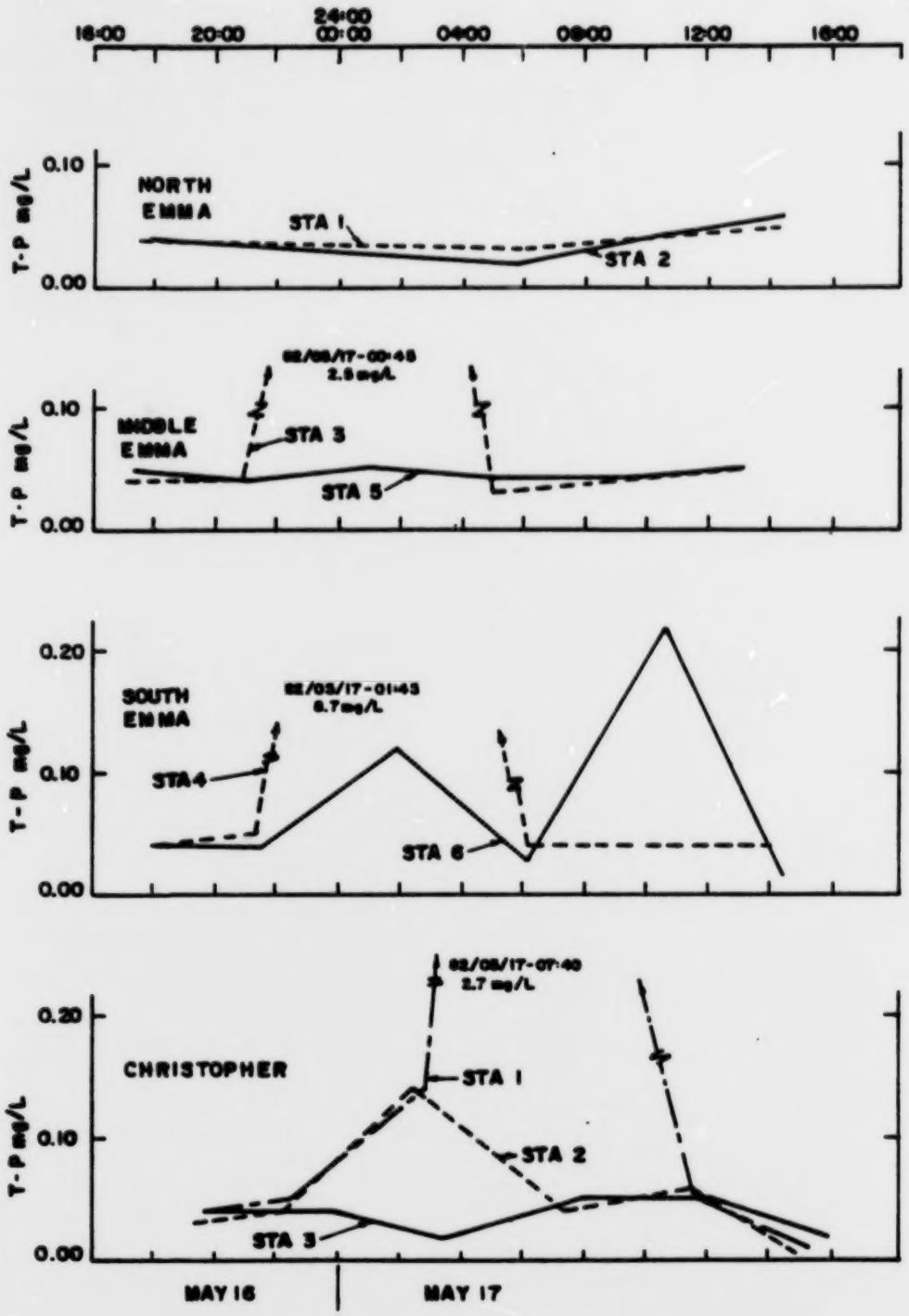
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL KJELDAHL NITROGEN - DIURNAL TRENDS - OCT/81		FIG. 2-3



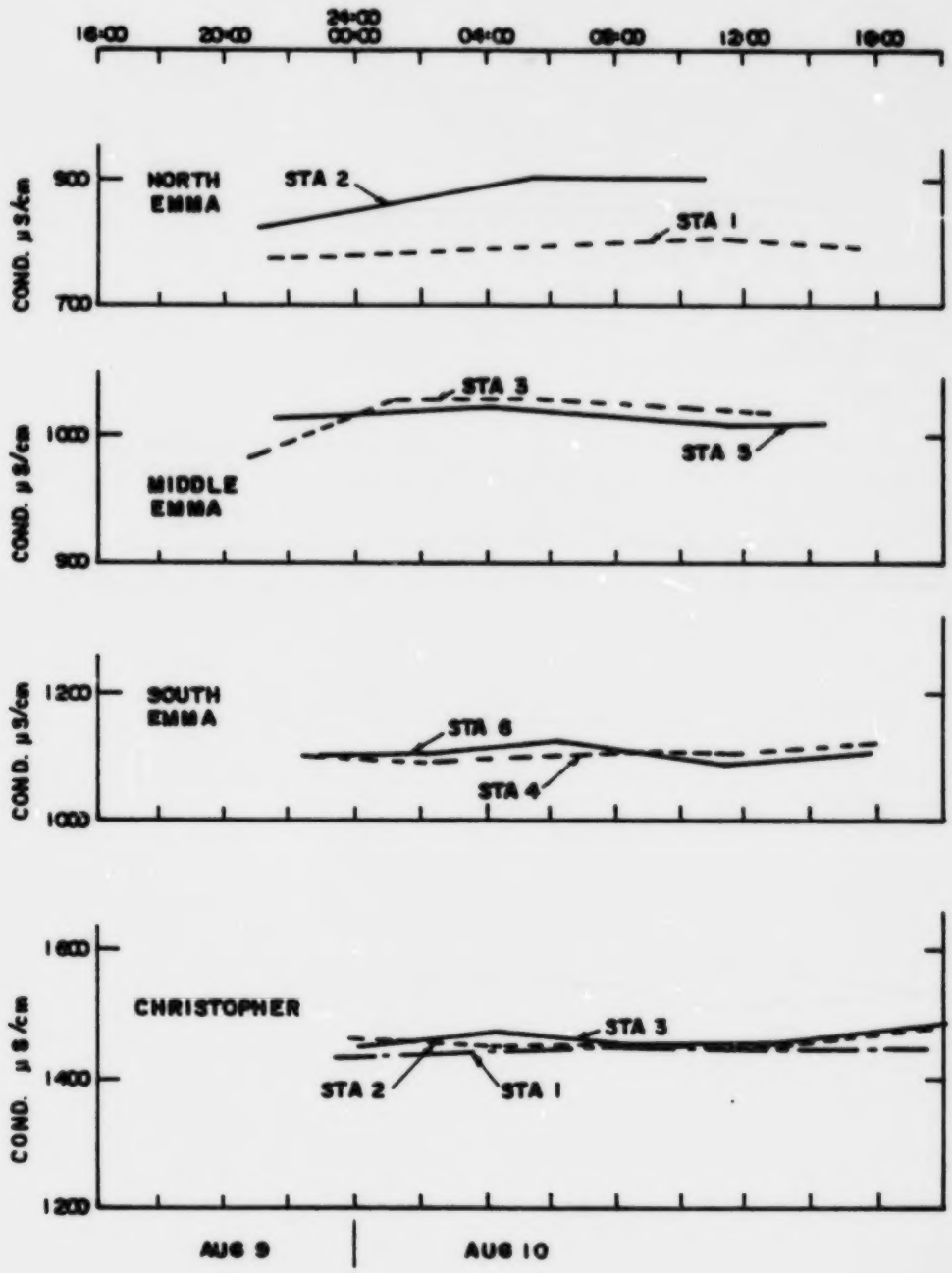
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL KJELDAHL NITROGEN-DIURNAL TRENDS- MAY/82		FIG.2-4



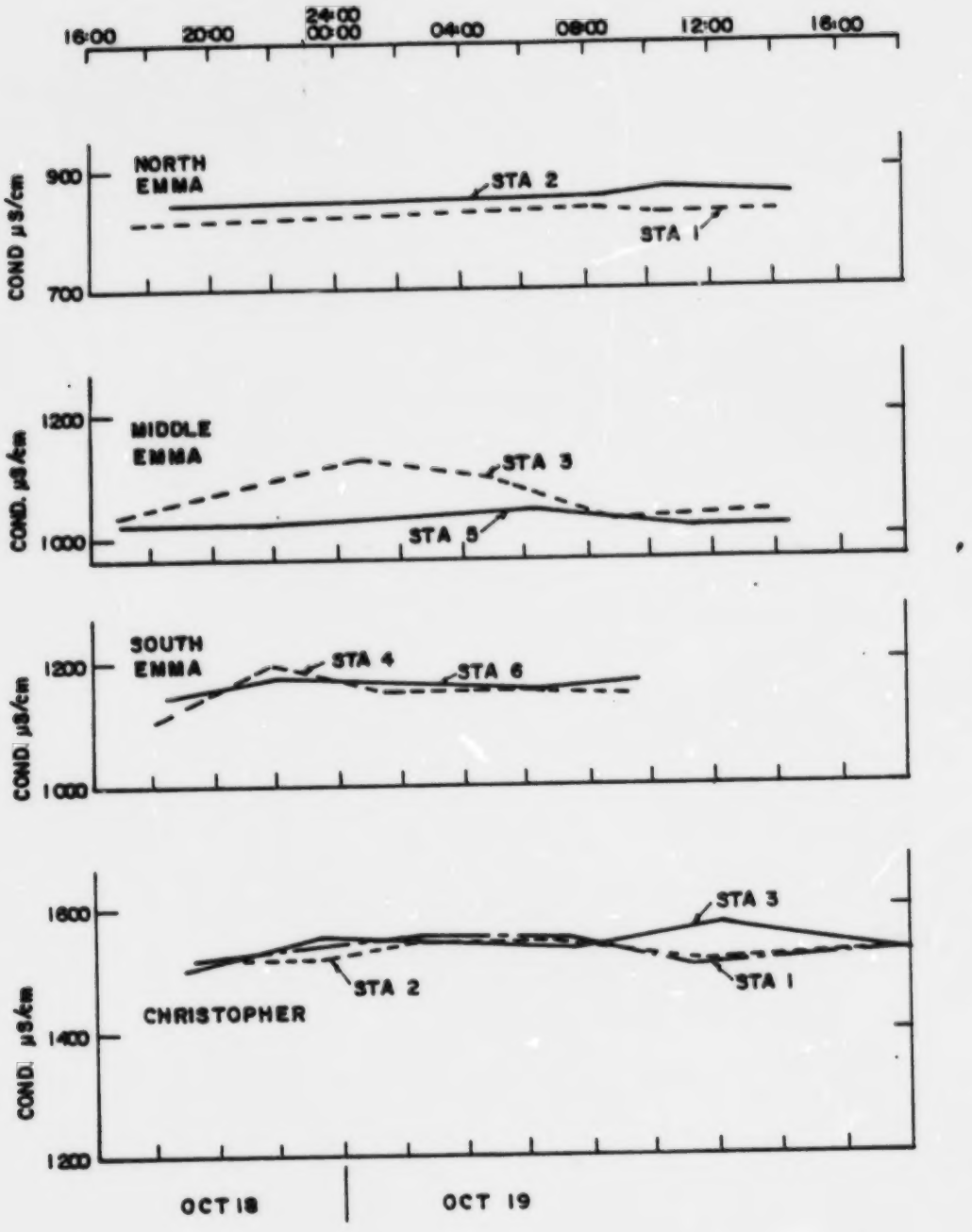
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL PHOSPHORUS - DIURNAL TRENDS - AUG/81		FIG.2-5



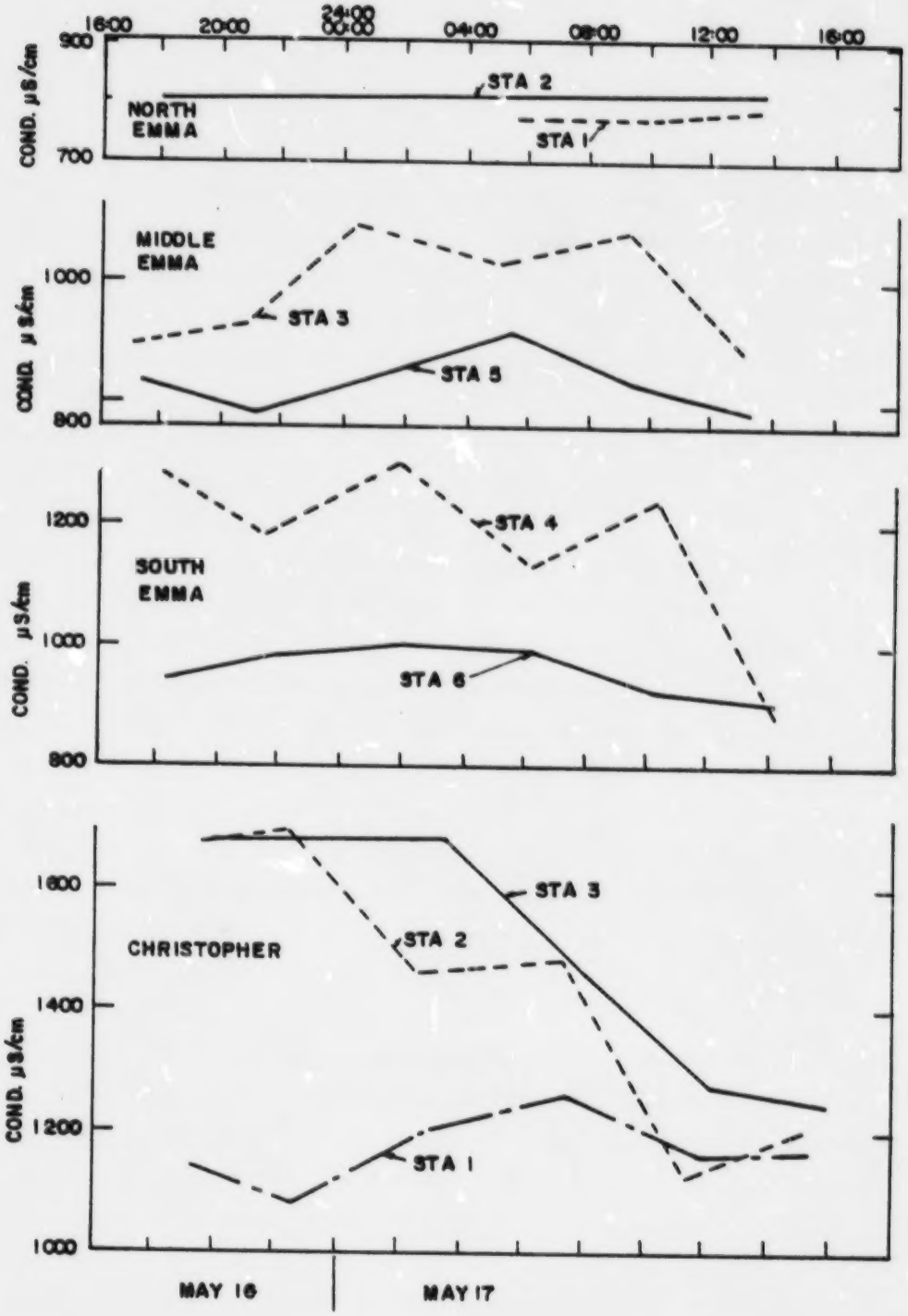
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL PHOSPHORUS - DIURNAL TRENDS - MAY/82		FIG.2-6



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
SPECIFIC CONDUCTANCE - DIURNAL TRENDS - AUG/81		FIG.2-7



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
SPECIFIC CONDUCTANCE - DIURNAL TRENDS - OCT/81		FIG. 2-8



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
SPECIFIC CONDUCTANCE - DIURNAL TRENDS - MAY/82		FIG.2-9

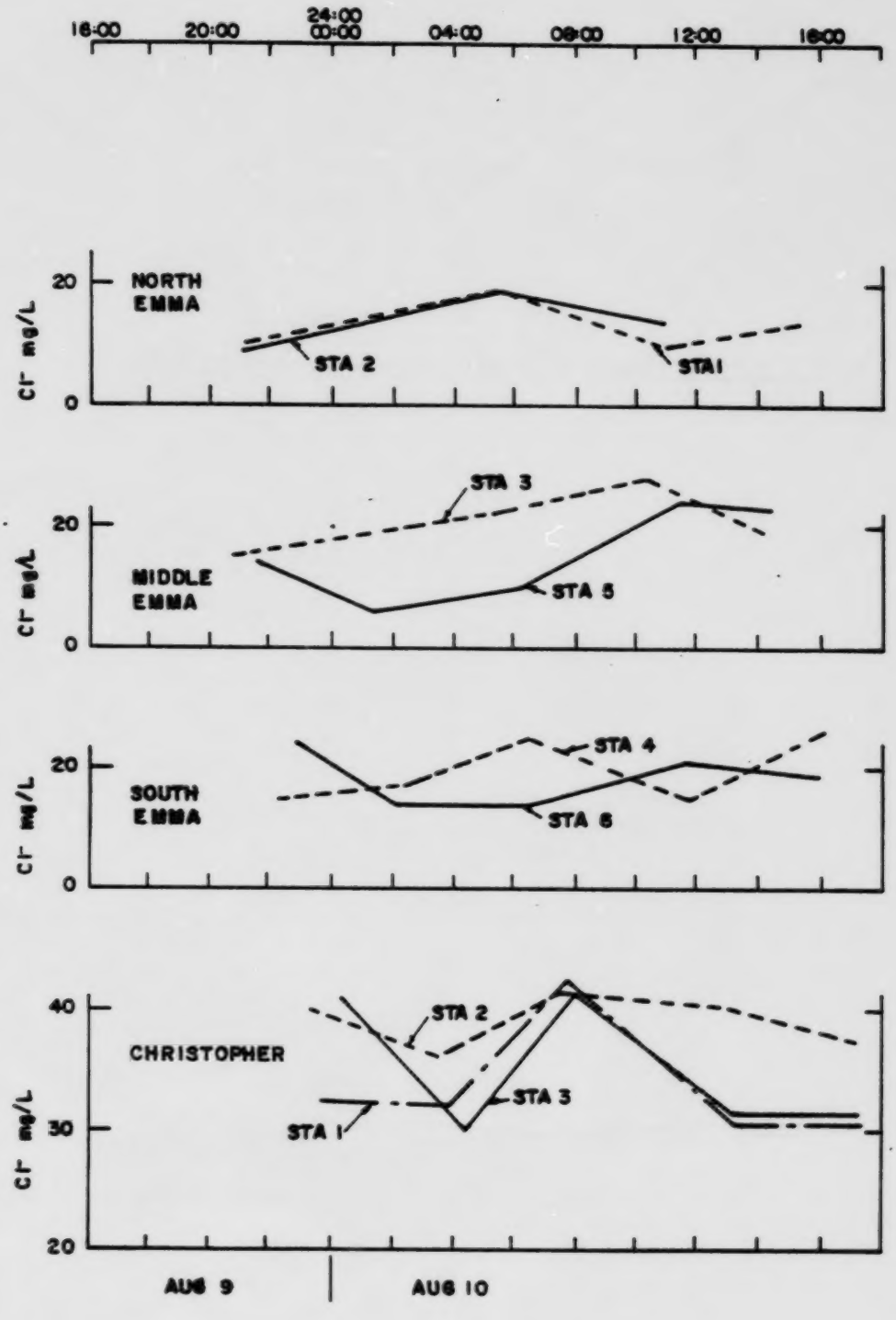
the trends were fairly uniform with the major differences occurring in the findings for each Emma Lake basin and Christopher Lake. However, the May.1982 samples revealed substantial differences--not only by time but also by stations within the basins and the lake. According to the data report, ice went off the lakes May 15 or the day previous to the commencement of sampling. (3) It appears very probable that this event largely contributed to the observations and that mixing had not been completed during the May 16-17 sampling time.

Figures 2.10, 2.11, and 2.12 provide the trends of chloride concentrations over the summer, fall, and spring periods. Chloride is frequently considered as quite conservative and stable with variations normally due to concentration by evaporation or ice formation or dilution by a lower chloride water inflow. While the fall observations were as typically expected, rather substantial variations were measured during the 24-hour periods in August 1981 and at virtually all the sites. Reasons for this atypical situation are not imminently clear. With the consistent trends of conductance, analytical/sampling error may be suspected for chloride. The spring period also had variations but, as noted previously, this may be attributed to the ice removal situation.

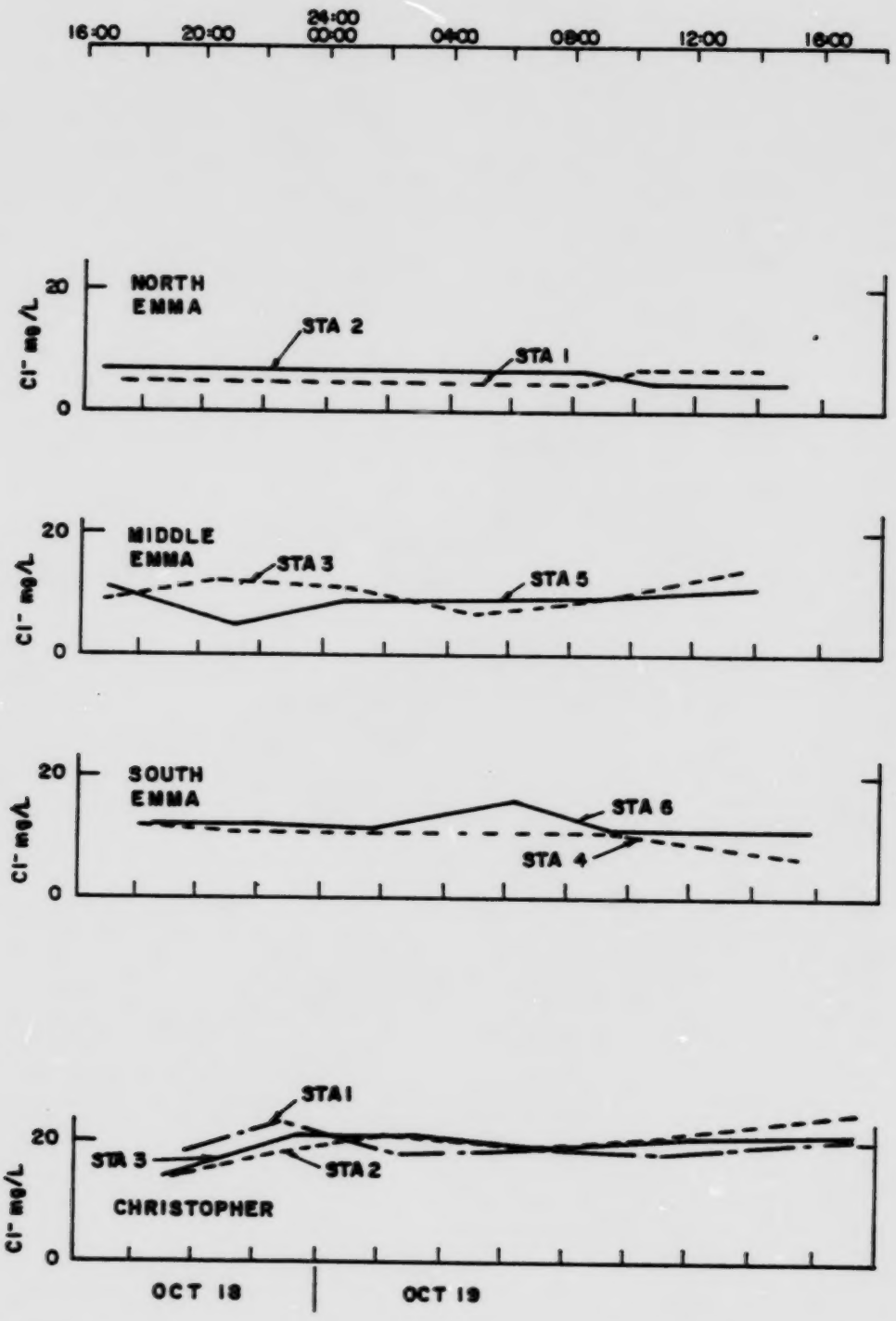
The diurnal data was also subjected to some statistical analysis, particularly to assess the variations that occurred. Tables A1 and A2, contained in the appendix, list the mean, median, standard deviation and coefficient of variation of the variables for the stations and seasons at Emma and Christopher Lakes respectively.

Using the coefficient of variation as an expression on the amount of variation about the mean values, the amount of variability within the diurnal monitoring program was generally observed tc rank from the largest to smallest as:

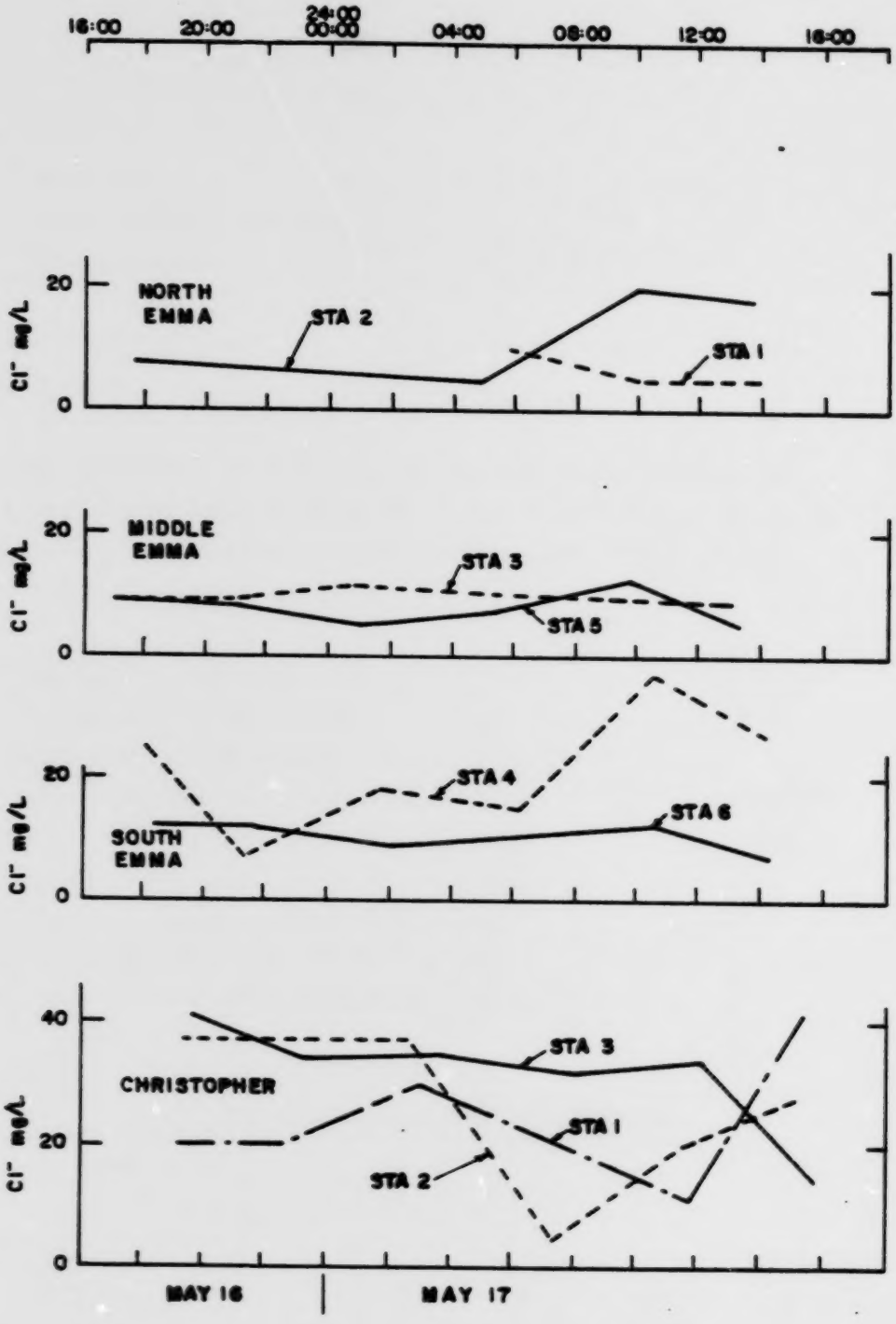
. total phosphorus



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
CHLORIDE - DIURNAL TRENDS - AUG /81		FIG. 2-10



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
	CHLORIDE - DIURNAL TRENDS - OCT/81	FIG.2-11



M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
CHLORIDE - DIURNAL TRENDS - MAY/82		FIG.2-12

- chloride
- total kjeldahl nitrogen
- conductance

This observation appears consistent with that from a visual inspection of the trends graphs.

In terms of the individual parameters, the variation was compared by season and site. Table 2.2 indicates the relative variability using the following arbitrary qualitative designations for coefficient of variation ranges:

Low (L) - less than 25%
Medium (M) - 25% - 75%
High (H) - 75% - 125%
Very High (VH) - greater than 125%

TABLE 2.2

EMMA AND CHRISTOPHER LAKES

DIURNAL DATA - RELATIVE VARIATIONS

Variable and Season	EMMA LAKE STATIONS						CHRISTOPHER LAKE STATIONS		
	1	2	3	4	5	6	1	2	3
Total kjeldahl nitrogen									
- Summer	L	L	L	L	L	L	L	L	L
- Fall	L	L	L	L	L	M	L	L	M
- Spring	M	M	L	M	L	L	L	L	M
Total phosphorus									
- Summer	H	M	H	H	H	VH	VH	M	H
- Fall	M	--	VH	M	H	VH	M	M	M
- Spring	L	M	VH	VH	L	H	VH	H	M
Conductance									
- Summer	L	L	L	L	L	L	L	L	L
- Fall	L	L	L	L	L	L	L	L	L
- Spring	L	L	L	L	L	L	L	L	L
Chloride									
- Summer	M	M	L	M	M	L	L	L	L
- Fall	M	M	M	L	L	L	L	L	M
- Spring	L	M	M	M	M	L	M	M	M

2.1.2 Daily Data

Daily samples were collected on three consecutive days for each of the seasons at all stations (No. 7, a control station, was only sampled in August 1981). The samples, approximate composites of the water column, were subjected to a fairly extensive range of analyses.

To visually assess the seasonal and station siting variability, the minimum and maximum ranges were plotted for key variables. Examples of these plots for five of the variables for each lake are appended as Figures A1 to A10.

In order to test for the effects of the seasons and the stations on the water quality data, a two-way classification analysis of variance (anova) was carried out. Based on the visual inspection and anticipated significance for assessing water quality, four variables--total organic carbon, chloride, total kjeldahl nitrogen, and total phosphorus--were selected for the analysis. Only the mid-lake stations were used. This testing of the means among the stations, among the seasons, and/or assessing the interaction of stations and seasons was carried out at a 5 percent significance level. Table 2.3 summarizes the findings.

In addition to the above, similar analyses were performed to test the effects respecting the beach and mid-lake stations, and the beach and shoreline control stations. The effects are noted in Table 2.4

It is noted that except for total phosphorus at the South Emma Lake sites, the effects of shoreline vs mid-lake stations are not significant. On the other hand, the time of year does provide significant differences for many of the variables at the selected stations.

TABLE 2.3

ANALYSIS OF VARIANCE - STATIONS-SEASONS

	Are Differences Significant For:		
	Mid-Lake Stations	4 Seasons	Stations-Seasons Interaction Effect
Emma Lake			
Total organic carbon	No	Yes	not significant
Chloride	No	No	"
Total kjeldahl nitrogen	Yes	Yes	"
Total phosphorus	No	No	"
Christopher Lake			
Total organic carbon	No	Yes	"
Chloride	No	Yes	"
Total kjeldahl nitrogen	No	No	
Total phosphorus	No	No	"

In order to obtain a general overall picture of water quality for the measured constituents and variables, a summary of observations for ice cover and open water conditions was prepared. The appendix contains tables indicating the mean, standard deviation, minimum, maximum, and median values for the variables at the Emma and Christopher Lakes stations. Tables 2.5 and 2.6 provide an overview, using the median observations. It should be noted that there were only three winter samples compared to nine samples under open water conditions. As a generality, concentrations of nutrients (nitrogen, phosphorus, and carbon) and inorganic indicator variables were larger during the ice cover period.

TABLE 2.4

ANALYSIS OF VARIANCE

MID-LAKE - SHORELINE STATIONS

	Are Differences Significant For:		Stations-Seasons Interaction Effect
	Stations	Seasons	
Emma Lake			
-Stations 3 & 5 - all seasons			
Total organic carbon	No	Yes	not significant
Chloride	No	No	not significant
Total kjeldahl nitrogen	No	Yes	not significant
Total phosphorus	No	No	not significant
-Stations 4 & 6 - all seasons			
Total organic carbon	No	Yes	not significant
Chloride	No	No	not significant
Total kjeldahl nitrogen	No	Yes	not significant
Total phosphorus	Yes	Yes	not significant
-Station 5 & 7 - Aug/81			
Total organic carbon	No	Yes	N/A
Chloride	No	No	
Total kjeldahl nitrogen	No	Yes	
Total phosphorus	No	No	
Christopher Lake			
-Stations 2 & 3 - all seasons			
Total organic carbon	No	Yes	not significant
Chloride	No	Yes	not significant
Total kjeldahl nitrogen	No	Yes	not significant
Total phosphorus	No	Yes	not significant
-Stations 3 & 4 - Aug & Oct			
Total organic carbon	No	Yes	significant
Chloride	No	No	not significant
Total kjeldahl nitrogen	No	No	not significant
Total phosphorus	No	No	not significant

TABLE 2.5

EMMA LAKE - 1981-82 WATER QUALITY

OPEN WATER AND ICE COVER - MEDIAN LEVELS

Variable	Open or ice	Station North Emma 1	2	Middle Emma 3	5	South Emma 4	6
Nitrogen, mg/L: Total kjeldahl	o	1.7	1.7	1.4	1.6	1.7	1.5
	i	3.1	2.8	1.9	2.1	1.9	1.9
Ammonia	o	0.12	0.15	0.13	0.13	0.14	0.15
	i	0.78	0.72	0.43	0.45	0.29	0.29
Nitrate	o	0.01	0.01	0.01	0.01	0.01	0.02
	i	0.01	0.005	0.03	0.03	0.02	0.01
Phosphorus, mg/L: Total	o	0.02	0.03	0.02	0.01	0.04	0.01
	i	0.06	0.05	0.05	0.04	0.08	0.03
ortho	o	0.01	0.01	0.01	0.01	0.01	0.01
	i	0.02	0.01	0.01	0.01	0.01	0.01
Carbon, mg/L: Total organic	o	31.0	31.0	28.0	26.0	29.0	26.0
	i	52.0	55.0	44.0	50.0	47.0	48.0
Inorganic	o	68.0	70.0	79.0	83.0	89.0	88.0
	i	99.0	97.0	88.0	88.0	88.0	93.0
Total Suspended Solids, mg/L	o	5.0	5.0	3.0	3.0	2.0	3.0
	i	2.0	2.0	1.0	1.0	1.0	1.0
Volatile Suspended Solids, mg/L	o	4.0	5.0	2.0	2.0	2.0	2.0
	i	2.0	2.0	1.0	1.0	1.0	1.0
Chlorophyll a, mg/m^3	o	4.0	4.0	5.0	5.1	3.4	4.5
	i	1.0	2.0	1.0	1.0	1.0	1.0
pH, units	o	8.6	8.7	8.6	8.7	8.7	8.8
	i	8.0	8.3	8.5	8.5	8.6	8.7
Specific Conductance, µS/cm	o	787	840	1040	1040	1130	1110
	i	1200	1240	1260	1300	1320	1370
Chloride, mg/L	o	7.0	10.0	14.0	14.0	14.0	11.0
	i	17.0	10.0	11.0	3.0	16.0	14.0
Iron, mg/L	o	0.02	0.02	0.02	0.01	0.01	0.01
	i	0.02	0.03	0.02	0.02	1.01	0.02
Manganese, mg/L	o	0.02	0.02	0.01	0.01	0.01	0.01
	i	0.13	1.0	0.01	0.02	0.002	0.01

TABLE 2.6

CHRISTOPHER LAKE - 1981-82 WATER QUALITY

OPEN WATER AND ICE COVER - MEDIAN LEVELS

Variable	Open or ice	Station 1	2	3	4
Nitrogen, mg/L: Total kjeldahl	o	1.7	1.8	1.6	2.0
	i	1.9	2.0	3.1	
Ammonia	o	0.16	0.15	0.16	0.15
	i	0.24	0.26	0.25	
Nitrate	o	0.001	0.01	0.01	0.01
	i	0.001	0.01	0.01	
Phosphorus, mg/L: Total	o	0.01	0.01	0.02	0.04
	i	0.05	0.05	0.05	
ortho	o	0.01	0.01	0.01	0.01
	i	0.01	0.01	0.01	
Carbon, mg/L: Total Organic	o	29.0	30.0	30.0	48.0
	i	80.0	60.0	65.0	
Inorganic	o	115.0	115.0	120.0	117.0
	i	130.0	120.0	139.0	
Total Suspended Solids, mg/L	o	2.0	2.0	2.0	3.0
	i	1.0	1.0	1.0	
Volatile Suspended Solids, mg/L	o	2.0	1.0	1.0	1.0
	i	1.0	1.0	1.0	
Chlorophyll a, mg/m^3	o	2.0	2.0	2.0	
	i	1.0	1.0	1.0	
pH, units	o	9.0	9.0	9.0	9.0
	i	8.9	8.9	8.9	
Specific Conductance, µS/cm	o	1470	1450	1490	1460
	i	1830	1700	1820	
Chloride, mg/L	o	21.0	27.0	21.0	40.0
	i	42.0	36.0	33.0	
Iron, mg/L	o	0.01	0.01	0.01	0.02
	i	0.01	0.01	0.02	
Manganese, mg/L	o	0.01	0.01	0.01	0.01
	i	0.01	0.01	0.01	

2.1.3 Sediments

Sediment samples were collected by an Ekman dredge from the mid-lake stations during August 12, 1981. Table 2.7 summarizes the general quality. It is noted that within Emma Lake, the south and middle basins were similar while the shallower north basin had lower nitrogen but higher phosphorus concentrations. The two sites in Christopher Lake had reasonably uniform quality, but somewhat different than observed in Emma Lake.

TABLE 2.7
EMMA AND CHRISTOPHER LAKES
SEDIMENTS - GENERAL QUALITY, AUGUST 1981

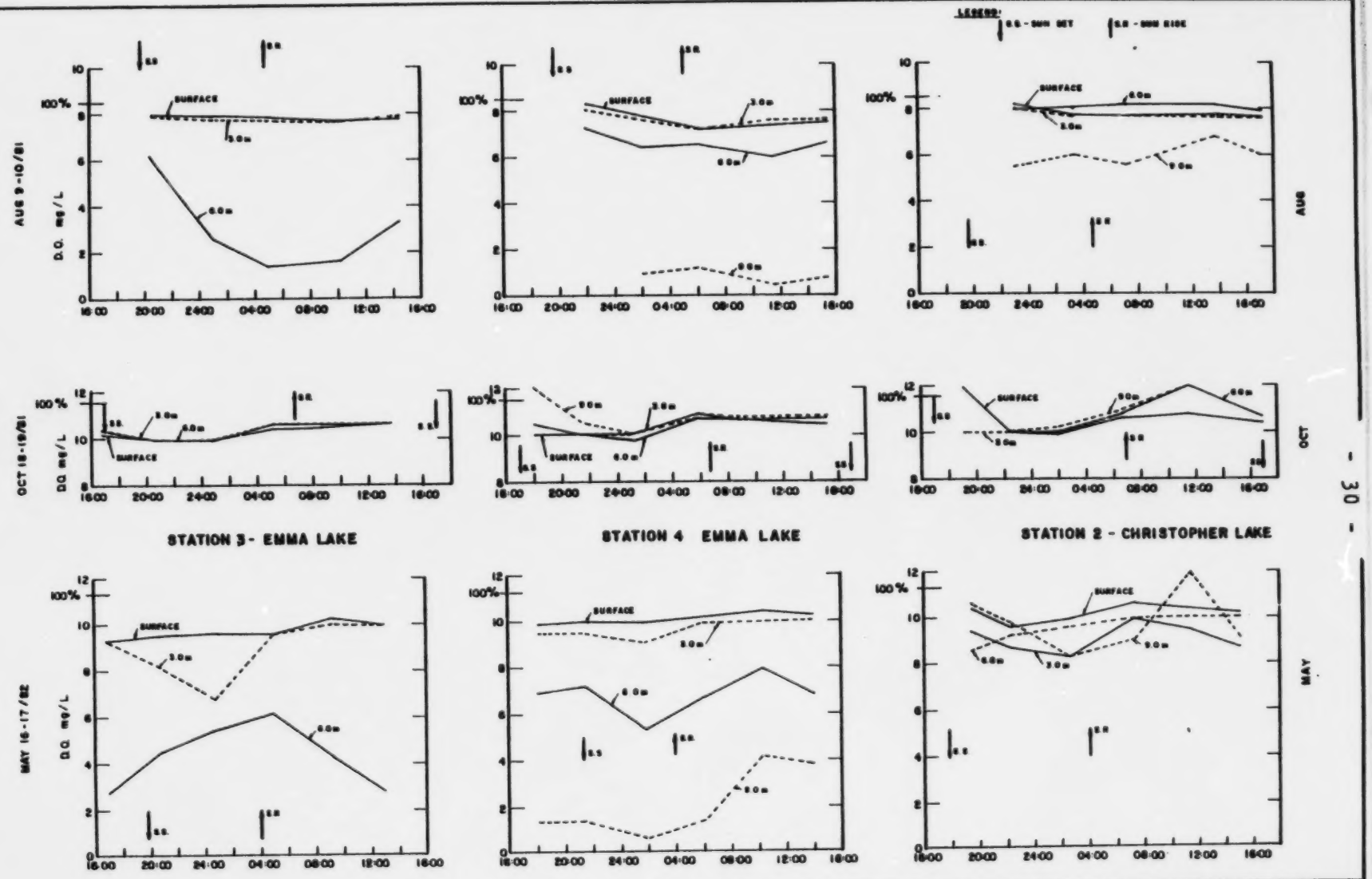
Variable	Emma Lake Stations 1	2	3	4	Christopher Lake Stations 1	2
Moisture (%)	90.0	95.2	95.3	94.5	94.0	93.4
Immediate Oxygen Demand (ug/g)	360	870	1200	1160	730	550
Carbon, Total Organic (%)	13.39	10.17	14.65	11.13	10.03	10.28
Carbon, Inorganic (%)	4.88	4.81	2.79	2.56	3.7	3.50
Nitrogen, Total Kjeld (ug/g)	3900	3600	5900	5800	3900	3400
Total Phosphorus (ug/g)	590	950	460	490	1040	900
Total Iron (ug/g)	9200	13000	16000	18000	16000	18000

2.2 Dissolved Oxygen

During the field study, dissolved oxygen measurements were made at all sampling occasions and at various lake water depths. The information provides an insight into the variations of dissolved oxygen with respect to season, 24-hour periods, and water depth.

Diurnal dissolved oxygen variations for three mid-lake stations (3 and 4 on Emma, and 2 on Christopher) over the August, October, and May periods are shown on Figure 2.13. The sites were chosen primarily because of their completeness of data. The concentrations measured at selected depths are plotted. During open water conditions, the classical concept is for minimum levels to occur during late night or very early morning and for maximum concentrations to develop in mid to late afternoon due to photosynthetic oxygen production by algae and other aquatic vegetation. Sunrise and sunset times are noted on the figure.

The expected sinusoidal curves were not readily observed particularly for the surface samples. It was noted the maximum levels during this diurnal monitoring did not significantly exceed 100 percent saturation and may suggest the algae populations were relatively low. The August period, which had a considerable duration of bright sunshine did not produce much variations in the upper three metres. However, below this depth, values were substantially lower and variable. October saw a relatively uniform time/depth oxygen regime develop. In May, particularly on Emma Lake, there was significant differences in the depth trends. It is recalled that ice-out occurred just prior to this monitoring and turnover may not have been completed.



M·R·2 CONSULTING ENGINEERS

EMMA AND CHRISTOPHER LAKES
1981-82 WATER QUALITY ASSESSMENT

DISSOLVED OXYGEN, DIURNAL TRENDS

DATE MARCH/83

FIG2-13

To determine the effect of water depth and the "health" of the oxygen regime, percent saturation values were calculated for all readings. Since water temperature significantly affects dissolved oxygen concentrations (i.e. at saturation, cold water has higher levels than warm water) the saturation values provide a better relative assessment. Minimum and maximum observed profiles were plotted to provide an envelope for the periods under review. Figures A11 to A18 in the appendix illustrate the findings for all stations and seasons at both lakes. The following are general comments:

- August 1981

  On Emma Lake, the oxygen levels were quite uniform except below the 6 m depths where rapid reductions were observed. In Middle Emma and in South Emma, levels below 5 mg/L were encountered at 5 and 7.5 m respectively.

  Christopher Lake was much more uniform. At station 2, levels decreased below 5 mg/L at 9 m depth.

- October 1981

  All values at all sites were very uniform throughout the water column and at levels exceeding 80 percent saturation.

- February 1982

  North Emma Lake was almost anoxic (without oxygen) at all depths measured. The mid-lake stations in the other basins showed stratification with maximum levels in the 60 percent saturation range. Below 5 mg/L concentrations were observed at depths of 6 m.

  Christopher Lake was less stratified in the mid-lake stations and all measurements exceeded 5 mg/L except at station 2 where lower values were determined at approximately the 6 m depth.

. May 1982
North Emma stations recovered to be in excess of 100 percent saturated. The other mid-lake sites also showed recovery although decreases with depth were still strong and less than 5 mg/L values were noted at approximately 4 m and 5 m depths for Middle and South Emma respectively.

Christopher Lake stations also showed increased values to the 80 percent or greater range. These sites were only weakly stratified.

2.3 Heavy Metals

2.3.1 Water

Water samples for analysis of nine heavy metals were collected from the mid-lake stations once each sampling period. Tables A5 & A6 in the appendix list the mean, standard deviation, minimum, maximum, and median values for the tested metals at the sites under open water and ice cover conditions. Due to the minimal data, stations were combined on a basin basis, eg. North Emma and Christopher. There were some significant differences between the winter - open water seasons. In particular, cadmium, chromium, and zinc had much higher ice cover concentrations. The open water levels of all the heavy metals were quite low.

2.3.2 Sediments

The sediment samples described in Section 2.1.3 were analyzed for the same variables measured in the water samples. The data are summarized in Table 2.8 . The sediment quality was reasonably uniform at the sites considered.

TABLE 2.8
EMMA AND CHRISTOPHER LAKES
SEDIMENTS - HEAVY METALS, AUGUST 1981

Analyte (units-dry basis)	Emma Lake Stations 1	2	3	4	Christopher Lake Stations 1	2
Manganese (ug/g)	43	69	61	59	43	58
Arsenic (ug/g)	5.7	5.7	5.7	5.9	5.7	5.9
Cadmium (ug/g)	L2	L2	2	L2	L2	L2
Chromium (ug/g)	20	25	30	32	30	43
Cobalt (ug/g)	L1	6	8	7	6	8
Copper (ug/g)	20	20	32	29	27	29
Nickel (ug/g)	20	L10	30	30	L20	L22
Lead (ug/g)	L20	L20	40	L20	20	20
Zinc (ug/g)	55	62	110	71	67	77
Mercury (ug/g)	0.12	0.25	0.24	0.22	0.14	0.16

2.3.3 Fish

Fish specimens were netted in North Emma Lake and Christopher Lake. The filetted tissue was analyzed for the common suite of heavy metals. Mean wet weight concentration for the metals by species are listed in Table 2.9. Complete analytical data is appended.

TABLE 2.9
EMMA AND CHRISTOPHER LAKES, 1981
HEAVY METALS - FISH
(mean concentration in ug/g or ppm)

	Emma		Christopher	
Metal	Walleye	Northern Pike	Walleye	Northern Pike
Arsenic	0.022	0.009	0.015	0.010
Cadmium	0.007	0.012	0.010	0.009
Chromium	0.106	0.089	0.084	0.107
Cobalt	0.005	0.007	0.0088	0.008
Copper	0.42	0.36	0.44	0.37
Nickel	0.08	0.02	0.06	0.080
Lead	0.07	0.08	0.05	0.09
Zinc	9.6	11.9	9.3	11.2
Mercury	0.75	0.60	1.15	1.03

2.4 Aquatic Biology

2.4.1 Bacteriology

During water sampling, bacteriological samples were taken for determination of indicator bacteria. These indicator bacteria are frequently used to assess the bacteriological safety of water. Table 2.10 lists the ranges of these bacteria counts for the summer, fall, and winter seasons. The May 1982 data has been omitted because of probable analytical problems. As noted from the table, the observed densities were quite low for the sites and dates in the monitoring program.

TABLE 2.10
EMMA - CHRISTOPHER LAKES
BACTERIOLOGICAL QUALITY
OBSERVED RANGES
(No/100 ML)

	EMMA LAKE STATIONS							CHRISTOPHER LAKE STATIONS			
	1	2	3	4	5	6	7	1	2	3	4
Total Coliforms											
- Summer (Aug 10-12/81)	L1	L2-4	L2-2	L2-2	4-12	L4-8	4-16	L2	L2	4-36	L2
- Fall (Oct 19-21/81)	L1-4	L2-4	2-14	2-4	L2-22	L2-2		L2-20	2-46	L2-6	
- Winter (Feb 23-24/81)	L1	L1-2	L1-L2	L1	L1	1-4		L1	L1-L4	L1-3	
Fecal Coliforms											
- Summer (Aug 10-12/81)	L2-1	L2	L2	L2-2	L2	L2-4	L2	L2	L2	L2-98	L2-2
- Fall (Oct 19-21/81)	L1-L2	L1-L2	L2-8	L2	L2	L2		L2	L2-2	L2	
- Winter (Feb 23-24/81)	L1	L1	L1	L1	L1	L2-1		L1	L1	L1	
Fecal Streptococci											
- Summer (Aug 10-12/81)	L1-L2	L2	L2	L2	L2	L2-8	L2-2	L2	L2	L2-16	L2-2
- Fall (Oct 19-21/81)	L1-1	L1-L2	L2	L1-L2	L2	L2		L2	L2-2	L1-2	
- Winter (Feb 23-24/81)	L1	L1	L1	L1	L1-1	L1		L1	L1	L1-3	

M · R · 2

2.4.2 Algae (Phytoplankton)

In conjunction with the daily water sampling program, samples for phytoplankton or algae were collected on the basis of composite samples for the mid-lake sites and samples at a 0.5 m depth for the shoreline stations. Other than the control stations, each station was sampled once during each season. Analyses consisted of counts and determination of species composition. The detailed lists of taxa and cell/colony counts are contained in the field study report. (3) The Integrated Environmental Sciences Inc. report also has a fairly complete description of the findings for the various survey times.

Table 2.11 provides a brief summary of the data for the major algae groupings, based on the species identified and the cell/colony counts. The predominant groups found in August 1981 are also noted on Figure A20.

Based on the count data, blue-greens and greens predominated in Emma Lake during the August sampling (Anabaena spiroides, Aphanocapsa elachista, and Tetraedron minimum). In Christopher Lake, blue-greens (Anabaena spiroides) were the major group with diatoms (Cymbella affinis) the secondary group. The subsequent seasonal trends were not unexpected.

Although the cell count numbers were fairly high, the chlorophyll data was reasonably consistent and low during the open water seasons. Christopher Lake had lower chlorophyll levels. Therefore, it would appear that the biomass concentrations were not unduly high. However, the presence of dominant blue-greens suggests a moderatly eutrophic condition. With the shallow nature of the lakes (particularly Emma) the water may be susceptible to algae blooms if certain climatic conditions such as prolonged elevated temperature persisted.

TABLE 2.11

PLANKTON SUMMARY

TYPES, SPECIES, CELL/COLONY COUNTS

	Emma Lake Stations										Christopher Lake Stations					
	1		2		3		5		4		6		1		2		3	
	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC	Sp	% TC
August 1981																		
Blue-green	11	39.5	15	55.1	11	65.2	7	53.1	10	31.3	11	44.9	2	37.0	3	79.3	7	85.4
Yellow-green	1	8.6	1	3.5	1	1.6	1	2.8	1	4.7	--	--	1	12.7	1	0.2	1	0.2
Green	14	43.3	10	22.4	14	11.6	11	13.6	11	19.2	12	10.2	8	10.9	6	3.0	7	2.7
Diatoms	7	8.1	7	18.5	6	20.9	7	30.1	7	43.5	11	44.2	4	38.6	3	15.8	7	10.2
Total Count	119,000		105,400		162,000		136,200		40,100		84,100		12,600		32,200		115,200	
October 1981																		
Blue-green	9	20.1	10	21.4	7	5.1	10	6.4	8	5.9	7	6.4	8	11.8	6	10.5	4	19.5
Yellow-green	1	45.8	1	40.3	1	24.3	1	30.3	1	20.7	1	28.2	1	68.2	1	70.7	1	38.1
Green	9	25.1	9	29.4	10	10.9	9	16.2	10	5.9	10	11.5	5	6.4	6	11.4	7	10.1
Diatoms	7	9.0	8	8.9	8	59.7	7	47.1	6	67.5	8	53.9	5	13.6	4	7.4	6	32.3
Total Count	94,600		96,600		117,000		148,200		86,100		57,100		19,000		26,400		20,800	
February 1982																		
Blue-green	2	98.1	2	61.5	--	--	1	--	1	--	--	--	1	13.0	3	25.4	1	2.8
Yellow-green	1	0.2	1	0.3	1	56.5	2	87.6	1	37.1	4	99.6	2	82.5	1	61.8	1	72.0
Green	3	0.4	2	1.3	3	4.2	1	--	3	2.9	1	--	--	--	3	--	--	--
Diatoms	--	--	--	--	5	39.3	1	12.4	6	60.0	2	0.4	1	4.5	3	12.8	3	25.2
Total Count	40,600		14,800		4,800		18,800		1,700		70,900		1,100		400		1,800	
May 1982																		
Blue-green	4	16.6	3	0.1	1	0.6	3	0.2	2	0.2	1	0.3	3	0.4	3	2.5	1	0.6
Yellow-green	5	25.5	5	42.1	4	66.6	3	42.4	2	67.5	3	56.5	1	49.7	3	17.9	3	3.9
Green	5	17.7	6	15.6	5	0.9	6	1.3	6	5.7	2	1.0	3	46.9	2	77.6	3	93.4
Diatoms	9	40.2	8	42.2	8	31.9	11	56.0	9	26.5	8	42.2	5	3.0	5	2.0	6	2.1
Total Count	62,500		97,000		256,500		60,100		17,500		141,900		109,500		126,800		155,100	

Notes: Sp - Number of species identified
% TC - Percent of total count
Total Count in cells or colonies per 100 mL

Blue-green - Cyanophyta
Yellow-green. - Cryptophyceae
Green - Chlorophyceae
Diatoms - Diatomeae

M.R.2

2.4.3 Aquatic Plants (Macrophytes)

During the field study, observations of submerged aquatic plants were made by skin-diving techniques and the dominant species, abundance, height, substrate type, and nuisance potential were noted. Emergent aquatic growths were also noted and mapped. The field observations were carried out near the end of July 1981. According to the field study report author, the data was not sufficient to produce a detailed distribution map of submerged macrophytes. (3)

The above field study report provides a comprehensive description of the aquatic vegetation observations. Table 2.12 provides a brief summary of the findings. Generally it appears that growths in shallow areas are retarded in areas of cottage development. In the deeper areas, where softer mud bottoms are more prevalent, fairly extensive submergent growth occurs. However, it appears this growth does not substantially impair recreational use. (3)

2.4.4 Bottom Living Organisms (Benthos)

Benthic macro invertebrates were collected from all mid-lake stations for each of the open water seasons. The Ekman dredge collected samples were field sieved prior to preservation. The May and October collections were archived and the August 1981 samples were examined for species composition and abundance. The finding are detailed in the study report. (3)

Essentially, the data suggests low species diversity for both lakes. The density at the Christopher Lake stations was much lower than in the major Emma Lake basins. The predominant species were Chaoborus punctipennis (phantom midge) and Chironomus plumosus (non-biting midge). The study report author noted the benthos to be indicative of moderately eutrophic to eutrophic conditions. (3)

TABLE 2.12

AQUATIC PLANT SUMMARY

Characteristics or Site	Emergent Growth Zone	Shallow Littoral Zone	Deep Littoral Zone
Typical Depths	1.0 - 1.5 metres	1.0 - 3.0 metres	2.0 - 5.0 metres
Coverage	common except near developed areas	5 - 30% relative bottom cover	50 - 80% relative bottom cover
Predominant species	Scirpus acutis (bulrush), Phragmatites communis, Carex sp, Typha sp (cattail)	Chara globularis (stonewort), Potamogeton filiformis (pondweed), also Potamogeton vaginatus, Utricularia vulgaris (bladderwort) and Myriophyllum sp (milfoil)	Potamegeton vaginatus (pondweed), Ruppia maritinia, Utricularia vulgaris, also Potamogeton pectinatus (sago pondweed), Myriophyllum sp (milfoil)
North Emma	Extensive on shoreline except in developed area	northeast--typical of deep zone--20 - 50% cover	some clean areas, > 2.0 m depth
Middle Emma	North third of lake	generally sparse in areas of development	2.0 - 4.0 m--dense growths--70 - 90% cover
South Emma	Generally limited to areas of no development	fairly sparse--sand, rocks	greatest density--up to 5.0 m--50 - 80% cover
Christopher Lake	Along shorelines with no development	sparse--hard sand or rocks--to 3 and 5 m	heaviest growth in lake at 3 - 6 m--30 - 60% cover > 6 m - less growth; absent at > 8 m

M · R · 2

Due to different life cycles, it may be fruitful to analyze the archived samples so that a more complete open water evaluation can be made. The single analyses would have to be considered as indicative rather than typical in terms of the benthos characteristics.

3. ASSESSMENT AND RECOMMENDATIONS

3.1 Water Use

The water use information was obtained from the earlier study reports and from conversation with Saskatchewan Health officials. (1) (2) Although the lake setting attracts related recreational activities, the direct uses are of primary interest.

3.1.1 Emma Lake

The following briefly itemizes main direct uses made of the lake:

- Potable consumption
- Non-potable domestic use
- Contact recreation--swimming/beaching
- Non-contact recreation--power boating, canoeing, sailing
- Fishing
- Propogation of fish and other aquatic organisms

3.1.2 Christopher Lake

The uses described for Emma Lake apply. It is understood a higher level of power boat use occurs on Emma Lake.

3.2 Impact on Uses

The following comments related to assessing the findings of the 1981-82 study in terms of the identified uses.

3.2.1 Potable Use

The frequency, quantity, and withdrawal sites of lake water used for potable purposes is unknown. In terms of general chemical quality, the

water would be satisfactory. Heavy metal concentrations are of potential concern. Two open water samples (North Emma and Christopher) had lead concentrations slighly in excess of maximum acceptable objectives. (7) The winter samples yielded excessive cadmium and chromium levels--significantly above the maximum acceptable objectives for drinking water--in both lakes. (7) It is unknown if the results are anomolies but unless the values are subsequently demonstrated to be lower, lake water consumption during the winter should be restricted or curtailed.

The lakes have reasonably good clarity but do contain material suspended in the water, including varying quantities and types of algae and other organisms. Although the bacteriological measurements were low, the lakes, like all open water bodies, are susceptible to bacteriological contamination. It is recommended that lake water not be used for consumption unless it has been properly disinfected. To ensure good disinfection, water should receive prior filtration.

3.2.2 Non-potable Domestic Use

The water should be satisfactory for this purpose. Care should be exercised to prevent consumption from any non-potable supply system.

3.2.3 Contact Recreation

Swimming and related contact recreational activities are often concerned with bacteriological quality, turbidity (clarity), algae, and aquatic weeds. It is noted that the presence of weed beds make some areas less desirable for swimming, etc. It is unknown if other weed problems such as beach accumulation occur. Based on available data, the activities should not be unduly restricted by turbidity or algae problems. The bacteriological data showed numbers well below current water quality objectives for this use. (8)

3.2.4 Non-contact Recreation

The water quality data, except for weed beds perhaps, does not suggest any impediments towards this use.

3.2.5 Fishing

The point of interest for fishing relates to the quality of the fish and its acceptability. Except for mercury, the information on heavy metal concentrations in Saskatchewan fish is rather limited. Comparable data for Fishing (Qu'Appelle) Lakes indicates Emma and Christopher fish to have similar or somewhat lower concentrations. (9)

However, mercury levels in the fish, collected in the survey, were high. The range of concentrations for Walleye were 0.52 to 0.94 ppm on Emma and 0.91 to 1.3 ppm on Christopher. Northern Pike ranges were from 0.41 to 0.94 ppm mercury in Emma and 0.69 to 1.4 ppm mercury in those from Christopher Lake. Virtually all of the values exceed the guidelines of 0.5 ppm for consumption.

Samples also collected in 1981 from Emma Lake as part of the provincial mercury-in-fish monitoring activity tended to have lower values means of 0.32 ppm and 0.21 ppm for Walleye and Pike respectively. (9) The reason for the apparent discrepancy of results is unknown. The fish sizes were comparable but the analytical laboratory differs and the fish collection sites may also have been different.

The 1981 sampling of this survey had a significant number of samples and therefore the findings should be of some concern. An advisory action respecting the limiting of fish consumption appears in order. Health officials should be consulted. In addition, followup surveillance is recommended.

3.2.6 Aquatic Ecology

In terms of habitat suitable for the rearing and sustenance of a fishery, considerations would include satisfactory conditions for spawning,

appropriate shelter and living environment, adequate food, absence of toxic or deleterious substances, and others such as an adequate dissolved oxygen regime. The field study did not directly review fish habitat conditions; however, the description of the aquatic vegetation and plant and animal life would tend to suggest those factors are satisfactory. Comments on potentially harmful substances or inadequate conditions can be made using the study data.

Of the determined constituents, generally the levels, excluding some for heavy metals, are below commonly accepted maximums for fish preservation purposes. The two critical concerns may be the ammonia nitrogen and dissolved oxygen concentrations. The ammonia nitrogen levels were observed to be higher during the February 1982 and May 1982 periods. Toxicity of ammonia nitrogen can be related to the amount of un-ionized ammonia which increases with temperature and pH. An un-ionized ammonia value of 0.02 mg/L has been used as a water quality objective. (10)

Calculated un-ionized ammonia concentrations yielded rather surprising results in that the August 1981 samples were higher for both lakes, and Christopher Lake tended to exhibit greater levels than Emma Lake. Table 3.1 illustrates the incidence of ammonia concentrations in excess of 0.02 mg/L.

Based on the calculated data, excessive ammonia levels were generated in Emma Lake during August 1981 and in Christopher Lake during all the sampling periods (only one measurement in October 1981). The concentrations in Christopher were significantly greater. However, this situation is probably more influenced by the higher pH recorded at Christopher rather than reflective of greater ammonia nitrogen values. It is noted the mid-lake samples were water column composites and thus higher values may be encountered at different depths.

TABLE 3.1

EMMA & CHRISTOPHER LAKES

CALCULATED UN-IONIZED AMMONIA LEVELS

(Table based on values greater than 0.02 mg/L)

	Emma Lake Stations							Christopher Lake Stations			
	North		Middle			South					
	1	2	3	5	7	4	6	1	2	3	4
Aug 10 - 12/81											
No. > 0.02 mg/L	3	3	3	3	3	3	3	3	3	3	3
Average, mg/L	0.025	0.030	0.029	0.029	0.034	0.031	0.036	0.056	0.057	0.065	0.058
Maximum, mg/L	0.027	0.032	0.03	0.035	0.036	0.033	0.037	0.058	0.061	0.074	0.064
Oct 19 - 21/81											
No. > 0.02 mg/L	0	0	0	0	-	0	0	1	0	0	-
Average, mg/L								0.022			
Maximum, mg/L	0.006	0.013	0.012	0.011	-	0.012	0.011	0.036	0.018	0.017	-
Feb 22 - 24/82											
No. > 0.02 mg/L	0	1	0	0	-	0	0	1	2	1	-
Average, mg/L		0.017						0.019	0.022	0.020	
Maximum, mg/L	0.015	0.022	0.017	0.015	-	0.015	0.014	0.021	0.024	0.022	-
May 17 - 19/82											
No. > 0.02 mg/L	0	0	0	0	-	0	2	3	3	3	-
Average, mg/L							0.021	0.029	0.035	0.036	
Maximum, mg/L	0.008	0.019	0.009	0.019	-	0.014	0.028	0.034	0.037	0.05	-

Some investigators have questioned the appropriateness of the 0.02 mg/L criterion. (11) A question is also raised as to the applicability of this low level to the indigenous fish of Emma and Christopher Lakes. However, the presented values should be of some concern and they would warrant some confirmatory testing.

The dissolved oxygen regime was quite variable in terms of sites, seasons, and depths. Emma Lake, at the deeper mid-lake stations in the middle and south basins, had stratified dissolved oxygen tendencils during all seasons except October. During August concentrations of less than 2 mg/L were encountered at depth of 6.0 m and 8.0 m for sites 3 and 4 respectively. The low D.O. zones were approximately 0.5 m and 2.0 m off the bottom for these sites. In May, only station 4 had levels below 2 mg/L--for about 1 m off the bottom. The ice cover finding indicated significant water column deficits at the deeper stations but only at the South Emma site were the levels below 2 mg/L and then only near the lake bottom. The stations in shallow North Emma had severe oxygen depletions during February. Al values were less than 1 mg/L.

In Christopher Lake, the dissolved oxygen picture was generally better. The deep mid-lake station, 2, exhibited some stratification in August and February but virtually all readings were in excess of 2 mg/L.

The 1981-82 data suggest, except for North Emma under ice cover, that the oxygen regime would be satisfactory for fish and other organisms. The north basin sites in February were essentially depleted of oxygen and would not normally sustain a fish population. It is suspected Emma Lake could be susceptible to dissolved oxygen problems if late year algae growths occurred or if summertime algae blooms developed followed by a rapid collapse of the growth under appropriate weather conditions. (12) (13)

. The aquatic vegetation, phytoplankton and macrophytes, generally seem to flourish which suggests the environmental conditions are favourable to their growth. The larger sized emergent and submergent plants may be mostly influenced by the substrate (hard sand/rock vs muds and organic materials) and development activities. Harder, less fertile bottom areas, and development areas generally produced less growth. It is unknown if any control measures have been practiced. Subsequent studies would be required to evaluate any trends in growth density or change in species dominance.

The level of water column nutrients, particularly nitrogen and phosphorus, suggest an adequate supply for moderate growths of algae. The waters from both lakes are not lacking in a nitrogen source with open water levels about 1.7 mg/L (TKN). The values are not unlike that found in the lakes of the Qu'Appelle River basin. (14) Phosphorus appears to be much lower than the Qu'Appelle Lakes (approximately 10 times), and this may be limiting to the production of extensive algae growths. Nitrogen to phosphorus ratios were fairly high (50 - 180 based on median levels) with Christopher Lake tending to be higher than Emma Lake. These ratios are significantly greater than those noted for lakes with eutrophication problems. (15)

The field study report noted the low species diversity for the benthic invertebrates and suggested some reasons for this occurrence. (3) It would appear that the effects of water quality on the growth of these bottom living organisms is not substantial, other than for the low oxygen levels that tend to favour more pollution tolerant species.

3.3 Other Water Quality Considerations

For some of the variables, significant concentration increases were noted during the winter sampling. In particular, nitrogen (total kjeldahl and ammonia), total phosphorus, total organic carbon, specific conductance,

chloride (Christopher Lake), some heavy metals exhibited increases. The changes in levels could be due to a concentrating effect due to formation of ice and/or due to chemical and biological activity of the bottom sediments.

The ice formation effect is difficult to predict since the physical data for the lakes is not complete. Based on the observed (February/82) ice thicknesses and estimated mean depths, the concentration factor for the lakes could have been.

North Emma - 160%
Middle Emma - 130%
South Emma - 120%
Christopher - 120%

These figures reasonably approximate increases in conductance but do not account for all the increases in ammonia nitrogen, phosphorus, carbon, and the heavy metals. It is speculated, for the first three variables, release from the sediments may have occurred due to reduction activity with low dissolved oxygen levels at the sludge-water interface.

The general sediment quality, based on the single set of samples, indicated some variability between the Emma Lake basins and Christopher Lake with respect to nitrogen and phosphorus. Middle and South Emma had higher TKN but lower phosphorus concentrations. Christopher Lake had the highest phosphorus levels. Winter water quality changes did not appear to be directly related to sediment concentrations. However, this sink could well be an input source if biochemical conditions are appropriate. It is noted the levels found at Emma and Christopher Lakes were not that dissimilar to those observed in the Fishing (Qu'Appelle) Lakes. (9)

The open water heavy metal concentrations tended to be below objective levels for the protection of aquatic life. Under ice cover, the single set of heavy metal data indicated significant increases for some of the

variables, eg. cadmium, chromium, copper (North Emma), nickel, and zinc. Of these, cadmium, chromium, and zinc exceeded some objectives. (7) (10) (16) .(17) Based on other data from Buffalo Pound Lake and the Fishing Lakes, the sediment heavy metal concentrations from Emma and Christopher Lakes are lower. (9) While it is conceivable the sediments are providing a substantial flux to the winter water, the low sediment concentrations and general aerobic conditions (except in North Emma) suggests further sampling would be in order to provide a better statistical base. It is noted that iron and manganese which tend to readily enter the water during winter conditions did not exhibit any increases approaching the magnitude observed for the aforementioned metals.

The fish tissue mercury levels present somewhat of a conundrum. All water analyses were reported to have mercury concentrations less than the detection limit (0.05 ug/L). Sediment mercury levels are comparable to those of Buffalo Pound Lake and much lower than the Fishing Lakes. (9) Given the lack of readily identifiable sources, the sediments would have to be considered the primary source in the biomagnification process.

In general, the water quality data for the Emma Lake basins and Christopher Lake are reasonably similar. However, there appears to be a marked difference in the dissolved salt concentrations as measured by specific conductance. For instance, during open water conditions, approximate levels were:

North Emma	-	815	uS/cm
Middle Emma	-	1040	uS/cm
South Emma	-	1120	uS/cm
Christopher	-	1470	uS/cm

For Emma Lake, this indicates the individuality of water quality within the three basins and also reflects the retention time of water flow.

3.4 Water Quality Surveillance

Based on the primary purposes noted in Section 1.1.2, the water quality surveillance program, as executed, could be considered successful in meeting those goals. Following review and analysis of the information obtained by the field study, a number of observations can be made with respect to the monitoring program and the findings. The following comments and/or recommendations are presented in an unpriorized order.

a) Since accurate pH measurements are useful and important, properly calibrated pH meters should be used for field work.

b) Measurement of biochemical oxygen demand in these lakes was not meaningful.

c) The diurnal measurements provided some interesting and unexpected results. The diurnal chloride variations are considered atypical. Phosphorus variability was particularly significant. In view of the plankton counts, there could be a substantial relationship between the plankton cycle and phosphorus measurements. The collection of a representative daily sample would seem to be difficult unless incremental samples over the period were composited.

d) Collection of samples immediately after ice-out yielded a highly erratic data set for that period. While the observations during this period are interesting, the instability does not provide an insight into representative pre-summer open water conditions. A few days following ice-out may be all the delay required.

e) Based on the analysis of variance for the selected variables, it would appear that generally the siting of stations is not critical but that the seasonal effects have a significant impact. Therefore, for a number of parameters, fewer sites may be appropriate as long as the temporal changes are accommodated.

f) The single set of winter heavy metal data produced some apparent anomolies which could not be confirmed by additional analyses. Thus confidence in this type of data is very weak. Replicate and/or quality control samples would strengthen the confidence. Because of the high values found and the use implications, followup work should be initiated at an early date.

g) The dissolved oxygen data generally supports the usefulness of diurnal and profile sampling.

h) Although a fairly extensive survey of macrophytes was conducted, a distribution map could not be prepared. To facilitate future comparisons, allowances should be made for a comprehensive survey.

i) A good indication of phytoplankton compostion and cell counts were obtained. Calculation of plankton volumes may better reflect biomass levels.

j) Early sampling should be considered to address the ammonia, wintertime heavy metals, and fish tissue mercury questions and concerns.

k) A similar comprehensive water quality surveillance program should probably be carried out within 5 to 8 years in order to assess trends and possible deterioration.

ACKNOWLEDGEMENTS

Appreciation is extended to the Water Pollution Control Branch staff especially K.P. Lautenschlager and M.M. Heisler for their assistance and participation.

REFERENCES

1. Ecologistics Limited. "A Study of Land and Water Use at Emma and Christopher Lakes, Final Report," March 1976.

2. Underwood McLellan Ltd. "Municipal Development Plan, Interim Report for the Rural Municipality of Lakeland," 1981.

3. Integrated Environmental Sciences Inc. "Results of a Field Program to Assess the Water Quality of Emma and Christopher Lakes, Saskatchewan, 1981-82," November 1982.

4. Mahood, H.D. "Emma, Christopher and Anglin Lakes Supplemental Hydrology Study," Saskatchewan Water Resources Commission, 1973.

5. Kupsch, W.O., in "Atlas of Saskatchewan" by J.H. Richards and K.I. Fung, 1969.

6. Anderson, D.W. and J.G. Ellis. "Soils of the Provincial Forest Reserve in the Prince Albert Map Area," Saskatchewan Institute of Pedology, No. SF3.

7. Saskatchewan Environment. "Municipal Drinking Water Quality Objectives," Water Pollution Control Branch, June 1980.

8. Saskatchewan Environment. " Water Quality Objectives," Water Pollution Control Branch, February 1977 Edition.

9. Saskatchewan Environment, Water Pollution Control Branch, unpublished data.

10. Davies, P.H. and J.P. Goette, Jr. "Aquatic Life--Water Quality Recommendations for Heavy Metal and Other Inorganic Toxicants in Fresh Water," Colorado Division of Wildlife, July 1976.

11. Szumski, D.S., et al. "Evaluation of EPA Un-ionized Ammonia Toxicity Criteria," Journal Water Pollution Control Federation, Vol. 54, No. 3, 1982.

12. Mathias, J.A. and J. Barica. "Factors Controlling Oxygen Depletion in Ice-covered Lakes," Can. J. Fish, Aquat. Sci, Vol.37, pp 185-194, 1980.

13. Papst, M.H., et al. "Relationship Between Thermal Stability and Summer Oxygen Depletion in a Prairie Pethole Lake, Can. J. Fish, Aquat. Sci., Vol 37, pp 1433-1438, 1980.

14. Saskatchewan Environment. "Annual Report 1981-82."

15. Smith, V.H. and J. Shapiro. "Chlorophyll-Phosphorus Relations in Individual Lakes. Their Importance to Lake Restoration Strategies," Environmental Science and Technology, Vol. 15, No. 4, 1981

16. Environment Canada. "Water Quality Sourcebook," Inland Waters Directorate, Water Quality Branch, 1979.

17. United States Environmental Protection Agency. "Summary of Water Quality Criteria," Federal Register, Vol. 45, No. 321, 1980.

APPENDICES

LIST OF APPENDICES

		Page No.
Comments on Statistical Analyses		58
Table A1	Emma Lake - 1981-82 Selected Variables - Univariate Analyses - Diurnal Samples	64
Table A2	Christopher Lake - 1981-82 Selected Variables - Univariate Analyses - Diurnal Samples	67
Table A3	Emma Lake - 1981-82 Water Quality - Open Water vs Ice Cover - Univariate Analyses - Daily Samples	70
Table A4	Christopher Lake - 1981-82 Water Quality - Open Water vs Ice Cover - Univariate Analyses - Daily Samples	72
Table A5	Emma Lake - 1981-82 Heavy Metals - Open Water vs Ice Cover - Univariate Analyses - Seasonal Samples	74
Table A6	Christopher Lake - 1981-82 Heavy Metals - Open Water vs Ice Cover - Univariate Analyses - Seasonal Samples	76
Table A7	Selected Climatological Data - Prince Albert Station	77
Table A8	Emma Lake, Fish Tissue - Heavy Metal Data	78
Table A9	Christopher Lake, Fish Tissue - Heavy Metal Data	79
Figure A1	Total Organic Carbon - Seasonal Ranges - Emma Lake	80
Figure A2	Chloride - Seasonal Ranges - Emma Lake	81
Figure A3	Total Kjeldahl Nitrogen - Seasonal Ranges - Emma Lake	82
Figure A4	Ammonia Nitrogen - Seasonal Ranges - Emma Lake	83
Figure A5	Total Phosphorus - Seasonal Ranges - Emma Lake	84
Figure A6	Total Organic Carbon-Seasonal Ranges-Christopher Lake	85
Figure A7	Chloride - Seasonal Ranges - Christopher Lake	86
Figure A8	Total Kjeldahl Nitrogen-Seasonal Ranges-Christopher Lake	87
Figure A9	Ammonia Nitrogen - Seasonal Ranges - Christopher Lake	88
Figure A10	Total Phosphorus - Seasonal Ranges - Christopher Lake	89
Figure A11	Dissolved Oxygen Profiles - Emma Lake - August 1981	90
Figure A12	Dissolved Oxygen Profiles - Emma Lake - October 1981	91

		Page No.
Figure A13	Dissolved Oxygen Profiles - Emma Lake - February 1982	92
Figure A14	Dissolved Oxygen Profiles - Emma Lake - May 1982	93
Figure A15	Dissolved Oxygen Profiles - Christopher Lake - August 1981	94
Figure A16	Dissolved Oxygen Profiles - Christopher Lake - October 1981	95
Figure A17	Dissolved Oxygen Profiles - Christopher Lake - February 1982	96
Figure A18	Dissolved Oxygen Profiles - Christopher Lake - May 1982	97
Figure A19	Selected Cross Sections	98
Figure A20	Miscellaneous Biological Information	99

COMMENTS ON STATISTICAL ANALYSES

Although the 1981-82 water quality monitoring program was comparatively extensive, the focus was on obtaining a basic inventory of information to examine diurnal, seasonal, and site location quality and a substantial amount of data was not generated. It was considered that the sample populations did not support a number of conventional or sophisticated statistical testing.

Essentially, the analyses utilized were the conventional mean, median, standard deviation, percentiles, coefficient of variation, etc., approval, and two-way analysis of variance. Procedures and software developed by Statistical Analysis System were used in concert with Esquadat stored data.

The SAS Univariate procedure was used to produce the standard statistics for diurnal data, heavy metal data, and open water-ice cover summaries. A copy of an output is appended. To compare the amount of variation in populations having different means, the coefficient of variation (Cv) was used. The Cv provides a relative measure of variation and is independent of the units used. This approach was applied to variables in the diurnal sampling program. It provided a reasonable relative assessment of the diurnal variability for the tested parameters.

The temporal and spatial characteristics of the samples can be determined by an analysis of variance. This analysis tests whether two or more sample means are significantly different. Very basically the analysis tests whether proposed hypotheses of the means are valid, eg. are they equal or not? (within a stipulated level of significance or probability)

The two-way classification of variance permits evaluation of the effects of two factors, such as stations and seasons, simultaneously. It is assumed that each factor contributes to the water quality and that the

two factors add their effects without influencing each other.

It was desired to assess the effects of the seasons and the station. For this exercise the daily data was used and four variables selected (based on an inspection of graphically plotted data and the probable importance of the variables). This data provided equal sample sizes and the three consecutive sampling days were considered as replicate samples for the season.

To generate the test statistics, the SAS General Linear Models procedure was used. A 5 percent level of significance was arbitrarily chosen. The null hypothesis to be accepted or rejected was that the means (stations, seasons) were equal. A standard F Table was used for the critical region definition. The tabulated results of the analysis are appended together with a copy of the computer output. The results were translated into an assessment respecting the significant difference of the means. An identification of which factor caused rejections was not pursued.

REFERENCES

Ponce, S.L. "Statistical Methods Commonly Used in Water Qualtiy Data Analysis." Watershed Systems Development Group, USDA Forest Service, Technical Paper WSDG-TP-00001, December 1980.

Sanders, T.G. ed. "Design of Water Quality Monitoring Network." Colorado State University, July 1979.

"SAS Users Guide." Statistical Analysis System, Cary, North Carolina, 1979 Edition.

UNIVARIATE

VARIABLE=TP

MOMENTS

N	5	SUM WGTS	5
MEAN	0.0658	SUM	0.329
STD DEV	0.056979	VARIANCE	0.0032472
SKEWNESS	1.551319	KURTOSIS	2.4106311
USS	0.034201	CSS	0.012968
CV	86.54071	STD MEAN	0.0254823
T:MEAN=0	2.581813	PROB>|T|	0.0602488
SGN RANK	7.5	PROB>|S|	0.0579073
NUM ^= 0	5		

QUANTILES(DEF=4)

100% MAX	0.16	99%	0.16
75% Q3	0.11	95%	0.16
50% MED	0.05	90%	0.16
25% Q1	0.045	10%	0.009
0% MIN	0.009	5%	0.009
		1%	0.009
RANGE	0.151		
Q3-Q1	0.065		
MODE	0.05		

EXTREMES

LOWEST	HIGHEST
0.009	0.009
0.05	0.05
0.05	0.05
0.06	0.06
0.16	0.16

M·R·2 CONSULTING ENGINEERS

DEPENDENT VARIABLE: TP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	15	5.13544033	0.34236269	0.99	0.4892	0.316572	456.5781
ERROR	32	11.08659533	0.34645610		STD DEV		TP MEAN
CORRECTED TOTAL	47	16.22203567			0.58860522		0.12891667

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
STN	5	0.96951683	0.93	0.4362	5	0.96951683	0.93	0.4362
SEA	1	1.15863233	1.11	0.3576	1	1.15863233	1.11	0.3576
STN*SEA	9	3.00729117	0.96	0.4864	9	3.00729117	0.96	0.4864

M·R·2 CONSULTING ENGINEERS

EMMA LAKE - ANALYSIS OF VARIANCE

	Variable	α	Stations			Seasons			Stations/Seasons		
			Fs	Fc	A/R	Fs	Fc	A/R	Fs	Fc	A/R
Stations 1, 2, 3, & 4 - All Seasons	TOC	0.05	1.56	2.91	A	31.69	2.91	R	1.75	2.20	A
	Cl	0.05	1.24	2.91	A	1.61	2.91	A	0.48	2.20	A
	TKN	0.05	4.87	2.90	R	12.40	2.90	R	1.71	2.19	A
	TP	0.05	0.93	2.90	A	1.11	2.90	A	0.96	2.19	A
Stations 3 & 5 - All Seasons	TOC	0.05	0.01	4.49	A	14.92	3.24	R	1.90	3.24	A
	Cl	0.05	0.12	4.49	A	0.81	3.24	A	0.99	3.24	A
	TKN	0.05	2.62	4.49	A	16.12	3.24	R	1.02	3.24	A
	TP	0.05	1.50	4.49	A	1.90	3.24	A	0.65	3.24	A
Stations 4 & 6 - All Seasons	TOC	0.05	0.01	4.49	A	9.35	3.24	R	0.10	3.24	A
	Cl	0.05	0.98	4.49	A	1.55	3.24	A	0.64	3.24	A
	TKN	0.05	0.80	4.49	A	5.59	3.24	R	0.08	3.24	A
	TP	0.05	6.18	4.49	R	8.50	3.24	F	0.27	3.24	A
Stations 5 & 7	TOC	0.05	0.00	4.67	A	10.38	3.71	R	*	--	--
	Cl	0.05	0.34	4.96	A	1.91	3.71	A	*	--	--
	TKN	0.05	1.56	4.96	A	13.50	3.71	R	*	--	--
	TP	0.05	0.38	4.96	A	7.82	3.71	R	*	--	--

M · R · 2 CONSULTING ENGINEERS

CHRISTOPHER LAKE - ANALYSIS OF VARIANCE

	Vari-able	∝	Stations			Seasons			Stations/Seasons		
			Fs	Fc	A/R	Fs	Fc	A/R	Fs	Fc	A/R
Stations 1 & 2 - All Seasons	TOC	0.05	0.73	4.49	A	56.79	3.24	R	1.83	3.24	A
	Cl	0.05	0.09	4.49	A	5.53	3.24	R	0.64	3.24	A
	TKN	0.05	1.29	4.49	A	1.31	3.24	A	2.02	3.24	A
	TP	0.05	2.50	4.49	A	2.76	3.24	A	2.51	3.24	A
Stations 2 & 3 - All Seasons	TOC	0.05	1.20	4.49	A	18.62	3.24	R	1.01	3.24	A
	Cl	0.05	0.00	4.49	A	4.61	3.24	R	0.21	3.24	A
	TKN	0.05	0.33	4.49	A	4.92	3.24	R	0.31	3.24	A
	TP	0.05	0.36	4.49	A	3.91	3.24	R	0.28	3.24	A
Stations 3 & 4 - August & October	TOC	0.05	5.88	5.99	A	16.73	5.99	R	11.31	5.14	R
	Cl	0.05	4.55	5.99	A	1.65	5.99	A	3.10	5.14	A
	TKN	0.05	5.80	5.99	A	1.93	5.99	A	3.87	5.14	A
	TP	0.05	1.03	5.99	A	0.97	5.99	A	3.10	5.14	A

TABLE A1

EMMA LAKE - 1981-82 SELECTED VARIABLES

UNIVARIATE ANALYSES - DIURNAL SAMPLES

Summer (Aug/81)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	1.6	1.6	.16	10.21
1	TP	.05	.05	.051	93.078
1	Cond.	784.	785.	1.5	1.52
1	C1	13.	12.	4.3	32.2
2	TKN	1.6	1.6	.30	18.96
2	TP	.06	.06	.046	74.086
2	Cond.	840.	849.	17.0	2.03
2	C1	14.	14.	5.0	35.7
3	TKN	1.6	1.5	.24	15.44
3	TP	.06	.04	.051	88.751
3	Cond.	1026.	1040.	36.9	3.60
3	C1	21.	19.	4.3	20.5
4	TKN	1.6	1.6	.13	8.25
4	TP	.07	.05	.056	85.407
4	Cond.	1100.	1100.	7.1	.64
4	C1	19.6	17.	5.5	27.85
5	TKN	1.7	1.6	.13	7.76
5	TP	.05	.07	.044	81.841
5	Cond.	1022.	1020.	13.0	1.28
5	C1	16.	16.	7.3	45.0
6	TKN	1.6	1.6	.08	5.30
6	TP	.08	.04	.099	130.021
6	Cond.	1102.	1100.	11.0	1.00
6	C1	18.	19.	4.4	23.9

TABLE A1 (Cont'd)

Fall (Oct/81)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	1.4	1.4	.26	18.11
1	TP	.01	.01	.005	43.923
1	Cond.	812.	820.	17.8	2.20
1	Cl	9.	7.	6.3	72.0
2	TKN	1.6	1.6	.31	19.71
2	TP	<.01	.01	--	--
2	Cond.	843.	850.	18.0	2.13
2	Cl	8.	7.	4.6	57.3
3	TKN	1.4	1.4	.13	9.71
3	TP	.05	.01	.12	221.118
3	Cond.	1050.	1070.	58.52	5.57
3	Cl	13.	11.	6.7	52.7
4	TKN	1.4	1.4	.21	14.97
4	TP	.01	.01	.004	38.374
4	Cond.	1143.	1140.	26.	2.35
4	Cl	11.	11.	2.6	23.3
5	TKN	1.5	1.5	.16	10.39
5	TP	.01	.01	.012	87.254
5	Cond.	1051.	1070.	48.12	4.58
5	Cl	9.	9.	2.3	24.4
6	TKN	1.2	1.5	.62	50.57
6	TP	.03	.01	.041	148.537
6	Cond.	1151.	1160.	1.5	1.46
6	Cl	13.	12.	2.3	18.0

TABLE A1 (Cont'd)

Spring (May/82)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	2.2	2.2	.82	37.11
1	TP	.04	.04	.008	20.412
1	Cond.	776.	777.	6.16	.79
1	Cl	6.	6.	1.5	24.0
2	TKN	2.3	2.3	.64	27.73
2	TP	.04	.04	.016	40.825
2	Cond.	809.	810.	3.8	.48
2	Cl	13.	13.	7.4	57.8
3	TKN	1.5	1.5	.16	10.65
3	TP	.45	.04	1.004	223.180
3	Cond.	984.	977.	93.7	9.5
3	Cl	11.	10.	4.3	38.1
4	TKN	1.9	1.7	.48	26.2
4	TP	1.49	.04	3.535	238.021
4	Cond.	1167.	1205.	153.4	13.15
4	Cl	19.	17.	11.1	60.17
5	TKN	1.4	1.4	.21	14.98
5	TP	.05	.05	.005	12.172
5	Cond.	826.	816.	47.3	5.7
5	Cl	8.	8.	2.7	34.7
6	TKN	1.4	1.4	.15	10.39
6	TP	.08	.04	.078	99.678
6	Cond.	957.	967.	40.9	4.28
6	Cl	11.	12.	2.1	19.7

Table A2

CHRISTOPHER LAKE 1981-82 SELECTED VARIABLES

UNIVARIATE ANALYSES-DIURNAL SAMPLES

Summer (Aug/81)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	1.7	1.7	.31	17.63
1	TP	.09	.0	.144	164.367
1	Cond.	1456.	1450.	8.9	.61
1	Cl	35.	34.	6.0	17.0
2	TKN	1.7	1.8	.19	11.00
2	TP	.05	.05	.032	60.293
2	Cond.	1440.	1440.	7.1	.49
2	Cl	38.	40.	4.7	12.5
3	TKN	1.5	1.6	.11	7.21
3	TP	.05	.05	.049	99.999
3	Cond.	1460.	1450.	14.1	.97
3	Cl	35.	33.	5.5	15.5

Table A2 (Cont'd)

Fall (Oct/81)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	1.5	1.4	.24	16.27
1	TP	.01	.01	.004	39.329
1	Cond.	1477.	1520.	128.7	8.7
1	Cl	19.	18.	2.0	10.2
2	TKN	1.6	1.7	.11	6.90
2	TP	.01	.01	.004	39.329
2	Cond.	1484.	1520.	108.3	7.3
2	Cl	19.	19.	3.2	16.5
3	TKN	1.7	1.6	.51	30.19
3	TP	.01	.01	.004	39.329
3	Cond.	1542.	1540.	30.4	2.0
3	Cl	23.	21.	9.6	41.8

Table A2 (Cont'd)

Spring (May/82)

Station	Variable	Mean	Median	Standard Deviation	Coefficient of Variation
1	TKN	1.5	1.5	.23	16.11
1	TP	.49	.05	1.079	216.616
1	Cond.	1165.	1155.	60.6	5.2
1	Cl	24.	20.	10.4	43.97
2	TKN	2.6	3.0	.64	24.46
2	TP	.05	.04	.045	85.239
2	Cond.	1441.	1470.	241.9	16.78
2	Cl	27.	33.	27.3	47.2
3	TKN	2.5	2.9	.67	26.76
3	TP	.04	.04	.014	37.262
3	Cond.	1502.	1570.	209.4	13.9
3	Cl	32.	34.	8.6	26.6

TABLE A3
EMMA LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 1 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 2 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 3 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total	open	9	1.7	0.5	1.1	1.7	2.8	9	1.8	0.6	0.9	1.7	2.9	9	1.5	0.1	1.3	1.4	1.7
Kjeldahl Nitrogen	ice	3	2.7	1.0	1.6	3.1	3.3	3	3.0	0.6	2.6	2.8	3.7	3	2.0	0.2	1.7	1.9	2.1
Total Phosphorus	open	9	0.03	0.03	0.01	0.02	0.09	9	0.50	1.40	0.01	0.03	4.1	9	0.06	0.10	0.01	0.02	0.33
	ice	3	0.07	0.03	0.05	0.06	0.11	3	0.06	0.02	0.05	0.05	0.09	3	0.06	0.10	0.05	0.05	0.07
Sp.Conductance	open	9	796	21	765	787	825	8	834	17	812	840	850	9	1023	69	882	1040	1090
	ice	3	1193	50	1140	1200	1240	3	1233	30	1200	1240	1260	3	1263	6.0	1260	1260	1270
pH	open	9	8.6	0.1	8.5	8.6	8.8	8	8.7	0.1	8.6	8.7	8.8	9	8.6	0.1	8.5	8.6	8.8
	ice	3	8.0	0.1	8.0	8.0	8.0	3	8.3	0.1	8.2	8.3	8.4	3	9.0	0.04	8.5	8.5	8.6
chloride	open	9	9.0	5.0	5.0	7.0	20.0	8	10.0	5.0	4.0	10.0	18.0	9	14.0	6.0	6.0	14.0	27.0
	ice	3	16.0	3.0	13.0	17.0	19.0	3	14.0	8.0	8.0	10.0	23.0	3	12.0	3.0	10.0	11.0	16.0
T.S.S.	open	9	5.0	3.0	1.0	5.0	8.0	8	5.0	3.0	2.0	5.0	9.0	9	3.0	2.0	1.0	3.0	6.0
	ice	3	2.0	1.0	1.0	2.0	3.0	3	2.0	0.6	2.0	2.0	3.0	3	1.0	0.06	1.0	1.0	1.0
V.S.S.	open	9	4.0	2.0	1.0	4.0	7.0	9	4.0	2.0	1.0	5.0	7.0	9	2.0	1.0	1.0	2.0	2.0
	ice	3	2.0	1.0	1.0	2.0	3.0	3	2.0	0.6	2.0	2.0	3.0	3	1.0	0.06	1.0	1.0	1.0
Total Inorganic	open	9	68.0	3.0	62.0	68.0	73.0	9	70.0	3.0	64.0	70.0	75.0	9	80.0	7.0	68.0	79.0	88.0
Carbon	ice	3	97.0	4.0	93.0	99.0	100.0	3	96.0	2.0	93 0	97.0	97.0	3	89.0	1.0	88.0	88.0	90.0
Total Organic	open	9	31.0	4.0	25.0	31.0	38.0	8	33.0	4.0	28.0	31.0	41.0	9	30.0	9.0	24.0	28.0	50.0
Carbon	ice	3	54.0	4.0	51.0	52.0	58.0	3	56.0	2.0	54.0	55.0	58.0	3	44.0	2.0	42.0	44.0	45.0
Ammonia Nitrogen	open	9	0.19	0.24	0.08	0.12	0.38	9	0.13	0.04	0.07	0.15	0.18	9	0.13	0.03	0.11	0.13	0.19
	ice	3	0.77	0.03	0.74	0.78	0.79	3	0.72	0.04	0.68	0.72	0.75	3	0.43	0.02	0.41	0.43	0.45
Nitrate Nitrogen	open	9	0.01	0.01	0.01	0.01	0.05	8	0.02	0.04	0.01	0.01	0.12	9	0.05	0.05	0.005	0.01	0.11
	ice	3	0.01	0.01	0.004	0.01	0.03	3	0.01	0.01	0.005	0.005	0.02	3	0.02	0.006	0.02	0.03	0.02
Ortho Phosphorus	open	9	0.01	0	0.01	0.01	0.01	8	0.01	0.004	0.01	0.01	0.02	9	0.01	0	0.01	0.01	0.01
	ice	3	0.02	0.01	0.01	0.02	0.02	3	0.01	0.006	0.01	0.01	0.02	3	0.02	0.01	0.01	0.01	0.03
Iron	open	9	0.02	0.01	0.01	0.02	0.04	9	0.02	0.02	0.01	0.02	0.06	9	0.02	0.01	0.01	0.02	0.03
	ice	3	0.02	0.01	0.01	0.02	0.03	3	0.03	0.01	0.02	0.03	0.04	3	0.02	0.007	0.01	0.02	0.03
Chlorophyll A	open	6	4.0	0.8	3.0	4.0	5.0	6	5.0	2.0	3.0	4.0	8.0	6	5.0	2.0	2.0	5.0	7.0
mg/m³	ice	3	1.0	0	1.0	1.0	1.0	3	2.0	0	2.0	2.0	2.0	3	1.0	0.06	1.0	1.0	1.0
Manganese	open	8	1.02	0.01	0.01	0.02	0.04	9	0.02	0.01	0.01	0.02	0.04	9	0.01	0.01	0.01	0.01	0.02
	ice	3	0.12	0.02	0.10	0.13	0.14	3	0.09	0.008	0.08	1.0	1.0	3	0.02	0.007	0.01	0.01	0.02

TABLE A3 (Cont'd)
EMMA LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 4 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 5 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 6 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total Kjeldahl Nitrogen	open	9	1.6	0.4	1.1	1.7	2.5	9	1.6	1.2	1.2	1.6	1.9	9	1.3	0.5	0.02	1.5	1.8
	ice	3	1.8	0.2	1.6	1.9	1.9	3	2.0	0.1	1.9	2.1	2.1	3	2.1	0.5	1.7	1.9	2.6
Total Phosphorus	open	9	0.03	0.02	0.01	0.04	0.05	9	0.02	0.02	0.01	0.01	0.05	9	0.02	0.01	0.01	0.01	0.03
	ice	3	0.08	0.01	0.07	0.08	0.09	3	0.05	0.02	0.03	0.04	0.07	3	0.05	0.03	0.03	0.03	0.09
Sp.Conductance	open	9	1102	84	881	1130	1150	9	1004	90	791	1040	1080	9	1084	91	899	1110	1160
	ice	3	1320	10	1310	1320	1330	3	1303	6	1300	1300	1310	3	1370	10	1360	1370	1380
pH	open	9	8.7	0.07	8.6	8.7	8.8	9	8.6	0.1	8.4	8.7	8.8	9	8.8	1.0	8.7	8.8	9.0
	ice	3	8.6	0.09	8.6	8.6	8.7	3	8.5	0.01	8.5	8.5	8.5	3	8.7	1.0	8.6	8.7	8.7
chloride	open	9	14.0	5.0	7.0	14.0	26.0	9	12.0	5.0	5.0	12.0	23.0	9	11.0	4.0	5.0	11.0	19.0
	ice	3	16.0	4.0	13.0	16.0	20.0	3	15.0	3.0	13.0	14.0	19.0	3	16.0	3.0	14.0	14.0	20.0
T.S.S.	open	9	2.0	1.0	1.0	2.0	3.0	9	3.0	2.0	1.0	3.0	6.0	9	4.0	5.0	1.0	3.0	17.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0
V.S.S.	open	9	2.0	1.0	1.0	2.0	2.0	9	2.0	1.0	1.0	2.0	2.0	9	2.0	1.0	1.0	2.0	4.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0
Total Inorganic Carbon	open	9	88.0	11.0	66.0	89.0	106.0	9	81.0	11.0	56.0	83.0	93.0	9	87.0	13.0	63.0	88.0	108.0
	ice	3	88.0	0	88.0	88.0	88.0	3	86.0	10.0	75.0	88.0	95.0	3	93.0	4.0	89.0	93.0	97.0
Total Organic Carbon	open	9	30.0	14.0	19.0	29.0	63.0	9	26.0	8.0	15.0	26.0	42.0	9	30.0	12.0	24.0	26.0	61.0
	ice	3	49.0	5.0	45.0	47.0	55.0	3	56.0	13.0	47.0	50.0	70.0	3	48.0	2.0	46.0	48.0	49.0
Ammonia Nitrogen	open	9	0.14	0.03	0.08	0.14	0.17	9	0.14	0.03	0.1	0.13	0.12	9	0.14	0.03	1.0	0.15	0.18
	ice	3	0.3	0.005	0.29	0.29	0.30	3	0.44	0.02	0.42	0.45	0.45	3	0.28	0.01	0.27	0.29	0.29
Nitrate Nitrogen	open	9	0.03	0.03	0.005	0.01	0.08	9	0.04	0.05	0.01	0.01	0.15	9	0.03	0.02	0.01	0.02	0.06
	ice	3	0.02	0.004	0.02	0.02	0.03	3	0.02	0.01	0.02	0.03	0.03	3	0.01	0.007	0.01	0.01	0.02
Ortho Phosphorus	open	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01
	ice	3	0.01	0.006	0.01	0.01	0.02	3	0.01	0.01	0.01	0.01	0.02	3	0.01	0.006	0.01	0.01	0.02
Iron	open	9	0.02	0.01	0.01	0.01	0.04	9	0.01	0.01	0.01	0.01	0.03	9	0.04	0.08	0.01	0.01	0.24
	ice	3	0.01	0.006	0.01	0.01	0.02	3	0.02	0.01	0.01	0.02	0.03	3	0.02	0.006	0.01	0.02	0.02
Chlorophyll A mg/m³	open	6	3.4	1.1	2.1	3.4	5.0	6	6.0	3.2	2.2	5.1	9.0	6	4.6	2.2	1.8	4.5	7.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	0.06	1.0	1.0	1.0	3	1.0	0.06	1.0	1.0	1.0
Manganese	open	9	0.1	0.006	0.01	0.01	0.03	9	0.01	0.003	0.01	0.01	0.02	9	0.01	0.01	0.01	0.01	0.03
	ice	3	0.002	0.001	0.002	0.002	0.003	3	0.02	0.001	0.02	0.02	0.02	3	0.01	0.006	0.01	0.01	0.01

TABLE A3
EMMA LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 1 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 2 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 3 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total	open	9	1.7	0.5	1.1	1.7	2.8	9	1.8	0.6	0.9	1.7	2.9	9	1.5	0.1	1.3	1.4	1.7
Kjeldahl Nitrogen	ice	3	2.7	1.0	1.6	3.1	3.3	3	3.0	0.6	2.6	2.8	3.7	3	2.0	0.2	1.7	1.9	2.1
Total Phosphorus	open	9	0.03	0.03	0.01	0.02	0.09	9	0.50	1.40	0.01	0.03	4.1	9	0.06	0.10	0.01	0.02	0.33
	ice	3	0.07	0.03	0.05	0.06	0.11	3	0.06	0.02	0.05	0.05	0.09	3	0.06	0.10	0.05	0.05	0.07
Sp.Conductance	open	9	796	21	765	787	825	8	834	17	812	840	850	9	1023	69	882	1040	1090
	ice	3	1193	50	1140	1200	1240	3	1233	30	1200	1240	1260	3	1263	6.0	1260	1260	1270
pH	open	9	8.6	0.1	8.5	8.6	8.8	8	8.7	0.1	8.6	8.7	8.8	9	8.6	0.1	8.5	8.6	8.8
	ice	3	8.0	0.1	8.0	8.0	8.0	3	8.3	0.1	8.2	8.3	8.4	3	9.0	0.04	8.5	8.5	8.6
chloride	open	9	9.0	5.0	5.0	7.0	20.0	8	10.0	5.0	4.0	10.0	18.0	9	14.0	6.0	6.0	14.0	27.0
	ice	3	16.0	3.0	13.0	17.0	19.0	3	14.0	8.0	8.0	10.0	23.0	3	12.0	3.0	10.0	11.0	16.0
T.S.S.	open	9	5.0	3.0	1.0	5.0	8.0	8	5.0	3.0	2.0	5.0	9.0	9	3.0	2.0	1.0	3.0	6.0
	ice	3	2.0	1.0	1.0	2.0	3.0	3	2.0	0.6	2.0	2.0	3.0	3	1.0	0.06	1.0	1.0	1.0
V.S.S.	open	9	4.0	2.0	1.0	4.0	7.0	9	4.0	2.0	1.0	5.0	7.0	9	2.0	1.0	1.0	2.0	2.0
	ice	3	2.0	1.0	1.0	2.0	3.0	3	2.0	0.6	2.0	2.0	3.0	3	1.0	0.06	1.0	1.0	1.0
Total Inorganic	open	9	68.0	3.0	62.0	68.0	73.0	9	70.0	3.0	64.0	70.0	75.0	9	80.0	7.0	68.0	79.0	88.0
Carbon	ice	3	97.0	4.0	93.0	99.0	100.0	3	96.0	2.0	93 0	97.0	97.0	3	89.0	1.0	88.0	88.0	90.0
Total Organic	open	9	31.0	4.0	25.0	31.0	38.0	8	33.0	4.0	28.0	31.0	41.0	9	30.0	9.0	24.0	28.0	50.0
Carbon	ice	3	54.0	4.0	51.0	52.0	58.0	3	56.0	2.0	54.0	55.0	58.0	3	44.0	2.0	42.0	44.0	45.0
Ammonia Nitrogen	open	9	0.19	0.24	0.08	0.12	0.38	9	0.13	0.04	0.07	0.15	0.18	9	0.13	0.03	0.11	0.13	0.19
	ice	3	0.77	0.03	0.74	0.78	0.79	3	0.72	0.04	0.68	0.72	0.75	3	0.43	0.02	0.41	0.43	0.45
Nitrate Nitrogen	open	9	0.01	0.01	0.01	0.01	0.05	8	0.02	0.04	0.01	0.01	0.12	9	0.05	0.05	0.005	0.01	0.11
	ice	3	0.01	0.01	0.004	0.01	0.03	3	0.01	0.01	0.005	0.005	0.02	3	0.02	0.006	0.02	0.03	0.02
Ortho Phosphorus	open	9	0.01	0	0.01	0.01	0.01	8	0.01	0.004	0.01	0.01	0.02	9	0.01	0	0.01	0.01	0.01
	ice	3	0.02	0.01	0.01	0.02	0.02	3	0.01	0.006	0.01	0.01	0.02	3	0.02	0.01	0.01	0.01	0.03
Iron	open	9	0.02	0.01	0.01	0.02	0.04	9	0.02	0.02	0.01	0.02	0.06	9	0.02	0.01	0.01	0.02	0.03
	ice	3	0.02	0.01	0.01	0.02	0.03	3	0.03	0.01	0.02	0.03	0.04	3	0.02	0.007	0.01	0.02	0.03
Chlorophyll A	open	6	4.0	0.8	3.0	4.0	5.0	6	5.0	2.0	3.0	4.0	8.0	6	5.0	2.0	2.0	5.0	7.0
mg/m³	ice	3	1.0	0	1.0	1.0	1.0	3	2.0	0	2.0	2.0	2.0	3	1.0	0.06	1.0	1.0	1.0
Manganese	open	8	1.02	0.01	0.01	0.02	0.04	9	0.02	0.01	0.01	0.02	0.04	9	0.01	0.01	0.01	0.01	0.02
	ice	3	0.12	0.02	0.10	0.13	0.14	3	0.09	0.008	0.08	1.0	1.0	3	0.02	0.007	0.01	0.01	0.02

TABLE A3 (Cont'd)
EMMA LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 4 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 5 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 6 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total	open	9	1.6	0.4	1.1	1.7	2.5	9	1.6	1.2	1.2	1.6	1.9	9	1.3	0.5	0.02	1.5	1.8
Kjeldahl Nitrogen	ice	3	1.8	0.2	1.6	1.9	1.9	3	2.0	0.1	1.9	2.1	2.1	3	2.1	0.5	1.7	1.9	2.6
Total Phosphorus	open	9	0.03	0.02	0.01	0.04	0.05	9	0.02	0.02	0.01	0.01	0.05	9	0.02	0.01	0.01	0.01	0.03
	ice	3	0.08	0.01	0.07	0.08	0.09	3	0.05	0.02	0.03	0.04	0.07	3	0.05	0.03	0.03	0.03	0.09
Sp.Conductance	open	9	1102	84	881	1130	1150	9	1004	90	791	1040	1080	9	1084	91	899	1110	1160
	ice	3	1320	10	1310	1320	1330	3	1303	6	1300	1300	1310	3	1370	10	1360	1370	1380
pH	open	9	8.7	0.07	8.6	8.7	8.8	9	8.6	0.1	8.4	8.7	8.8	9	8.8	1.0	8.7	8.8	9.0
	ice	3	8.6	0.09	8.6	8.6	8.7	3	8.5	0.01	8.5	8.5	8.5	3	8.7	1.0	8.6	8.7	8.7
chloride	open	9	14.0	5.0	7.0	14.0	26.0	9	12.0	5.0	5.0	12.0	23.0	9	11.0	4.0	5.0	11.0	19.0
	ice	3	16.0	4.0	13.0	16.0	20.0	3	15.0	3.0	13.0	14.0	19.0	3	16.0	3.0	14.0	14.0	20.0
T.S.S.	open	9	2.0	1.0	1.0	2.0	3.0	9	3.0	2.0	1.0	3.0	6.0	9	4.0	5.0	1.0	3.0	17.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0
V.S.S.	open	9	2.0	1.0	1.0	2.0	2.0	9	2.0	1.0	1.0	2.0	2.0	9	2.0	1.0	1.0	2.0	4.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	1.0
Total Inorganic Carbon	open	9	88.0	11.0	66.0	89.0	106.0	9	81.0	11.0	56.0	83.0	93.0	9	87.0	13.0	63.0	88.0	108.0
	ice	3	88.0	0	88.0	88.0	88.0	3	86.0	10.0	75.0	88.0	95.0	3	93.0	4.0	89.0	93.0	97.0
Total Organic Carbon	open	9	30.0	14.0	19.0	29.0	63.0	9	26.0	8.0	15.0	26.0	42.0	9	30.0	12.0	24.0	26.0	61.0
	ice	3	49.0	5.0	45.0	47.0	55.0	3	56.0	13.0	47.0	50.0	70.0	3	48.0	2.0	46.0	48.0	49.0
Ammonia Nitrogen	open	9	0.14	0.03	0.08	0.14	0.17	9	0.14	0.03	0.1	0.13	0.12	9	0.14	0.03	1.0	0.15	0.18
	ice	3	0.3	0.005	0.29	0.29	0.30	3	0.44	0.02	0.42	0.45	0.45	3	0.28	0.01	0.27	0.29	0.29
Nitrate Nitrogen	open	9	0.03	0.03	0.005	0.01	0.08	9	0.04	0.05	0.01	0.01	0.15	9	0.03	0.02	0.01	0.02	0.06
	ice	3	0.02	0.004	0.02	0.02	0.03	3	0.02	0.01	0.02	0.03	0.03	3	0.01	0.007	0.01	0.01	0.02
Ortho Phosphorus	open	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01
	ice	3	0.01	0.006	0.01	0.01	0.02	3	0.01	0.01	0.01	0.01	0.02	3	0.01	0.006	0.01	0.01	0.02
Iron	open	9	0.02	0.01	0.01	0.01	0.04	9	0.01	0.01	0.01	0.01	0.03	9	0.04	0.08	0.01	0.01	0.24
	ice	3	0.01	0.006	0.01	0.01	0.02	3	0.02	0.01	0.01	0.02	0.03	3	0.02	0.006	0.01	0.02	0.02
Chlorophyll A mg/m³	open	6	3.4	1.1	2.1	3.4	5.0	6	6.0	3.2	2.2	5.1	9.0	6	4.6	2.2	1.8	4.5	7.0
	ice	3	1.0	0.06	1.0	1.0	1.0	3	1.0	0.06	1.0	1.0	1.0	3	1.0	0.06	1.0	1.0	1.0
Manganese	open	9	0.1	0.006	0.01	0.01	0.03	9	0.01	0.003	0.01	0.01	0.02	9	0.01	0.01	0.01	0.01	0.03
	ice	3	0.002	0.001	0.002	0.002	0.003	3	0.02	0.001	0.02	0.02	0.02	3	0.01	0.006	0.01	0.01	0.01

TABLE A4
CHRISTOPHER LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 1 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 2 Smpls	Mean	Std.Dev.	Min.	Med.	Max.	STATION 3 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total	open	9	1.7	0.3	1.1	1.7	2.1	9	1.8	0.5	1.3	1.8	3.0	9	1.9	0.5	1.2	1.6	2.8
Kjeldahl Nitrogen	ice	3	2.0	0.2	1.8	1.9	2.2	3	2.3	0.7	1.9	2.0	3.1	3	2.7	0.6	2.0	3.1	3.1
Total Phosphorus	open	9	0.01	0.005	0.01	0.01	0.02	9	0.04	0.06	0.01	0.01	0.19	9	0.03	0.03	0.01	0.02	0.11
	ice	3	0.05	0.01	0.05	0.05	0.06	3	0.05	0	0.05	0.05	0.05	3	0.05	0.02	0.03	0.05	0.06
Sp.Conductance	open	9	1388	161	1150	1470	1530	9	1447	147	1200	1450	1670	9	1472	98	1240	1490	1590
	ice	3	1813	29	1780	1830	1830	3	1703	45	1660	1700	1750	3	1833	42	1800	1820	1880
pH	open	9	9.0	0.07	8.9	9.0	9.1	9	9.0	1.0	8.8	9.0	9.1	9	9.0	1.0	8.9	9.0	9.0
	ice	3	9.0	0.01	8.9	8.9	8.9	3	8.9	0.01	8.9	8.9	8.9	3	8.9	0.01	8.9	8.9	8.9
chloride	open	9	24.0	7.0	18.0	21.0	41.0	9	27.0	7.0	16.0	27.0	37.0	9	26.0	9.0	16.0	21.0	44.0
	ice	3	40.0	12.0	27.0	42.0	50.0	3	37.0	6.0	32.0	36.0	43.0	3	38.0	10.0	32.0	33.0	50.0
T.S.S.	open	9	2.0	1.0	1.0	2.0	5.0	9	3.0	2.0	1.0	2.0	8.0	9	2.0	1.0	1.0	2.0	4.0
	ice	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	2.0	3	1.0	1.0	1.0	1.0	2.0
V.S.S.	open	9	2.0	1.0	1.0	2.0	5.0	9	2.0	1.0	1.0	1.0	4.0	9	2.0	1.0	1.0	1.0	2.0
	ice	3	1.0	1.0	1.0	1.0	1.0	3	1.0	1.0	1.0	1.0	2.0	3	1.0	0	1.0	1.0	1.0
Total Inorganic Carbon	open	9	108.0	14.0	84.0	115.0	120.0	9	102.0	31.0	24.0	115.0	120.0	9	118.0	10.0	98.0	120.0	135.0
	ice	3	127.0	6.0	120.0	130.0	130.0	3	119.0	3.0	116.0	120.0	121.0	3	123.0	29.0	89.0	139.0	140.0
Total Organic Carbon	open	9	35.0	13.0	22.0	29.0	63.0	9	36.0	17.0	12.0	30.0	65.0	9	39.0	13.0	27.0	30.0	59.0
	ice	3	77.0	6.0	70.0	80.0	80.0	3	64.0	8.0	59.0	60.0	74.0	3	74.0	24.0	56.0	65.0	101.0
Ammonia Nitrogen	open	9	0.16	0.05	0.07	0.16	0.21	9	0.16	0.08	0.07	0.15	0.31	9	0.16	0.07	0.07	0.16	0.30
	ice	3	0.25	0.03	0.23	0.24	0.28	3	0.26	0.03	0.23	0.26	0.29	3	0.26	0.02	0.25	0.25	0.29
Nitrate Nitrogen	open	9	0.15	0.43	0.005	0.001	1.3	9	0.01	0.02	0.01	0.01	0.01	9	0.01	0.01	0.005	0.01	0.03
	ice	3	0.01	0.001	0.01	0.01	0.01	3	0.01	0.002	0.01	0.01	0.01	3	0.005	0.001	0.004	0.01	0.01
Ortho Phosphorus	open	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01
	ice	3	0.02	0.01	0.01	0.01	0.03	3	0.02	0.01	0.01	0.01	0.03	3	0.02	0.01	0.01	0.01	0.03
Iron	open	9	0.02	0.01	0.01	0.01	0.04	9	0.02	0.01	0.01	0.01	0.03	9	0.01	0.01	0.01	0.01	0.03
	ice	3	0.01	0.004	0.01	0.01	0.02	3	0.01	0.005	0.01	0.01	0.02	3	0.02	0.002	0.02	0.02	0.02
Chlorophyll A mg/m³	open	6	2.0	1.0	1.0	2.0	4.0	6	1.0	0.8	1.0	2.0	2.0	6	2.0	1.0	1.0	2.0	3.0
	ice	3	1.0	1.0	1.0	1.0	1.0	3	1.0	0	1.0	1.0	1.0	3	1.0	0.1	1.0	1.0	1.0
Manganese	open	8	0.01	0.001	0.01	0.01	0.01	9	0.01	0.001	0.01	0.01	0.01	9	0.01	0	0.01	0.01	0.01
	ice	3	0.01	0.001	0.01	0.01	0.01	3	0.01	0	0.01	0.01	0.01	3	0.01	0.001	0.01	0.01	0.01

TABLE A4
CHRISTOPHER LAKE - 1981-82 WATER QUALITY
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - DAILY SAMPLES

(Units in mg/L unless noted)

Variable		STATION 4 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Total Kjeldahl Nitrogen	open	3	2.0	0.06	2.0	2.0	2.0
	ice						
Total Phosphorus	open	3	0.08	1.0	0.01	0.04	0.2
	ice						
Sp.Conductance	open	3	1460	10.0	1450	1460	1470
	ice						
pH	open	3	9.0	0.01	9.0	9.0	9.0
	ice						
chloride	open	3	41.0	16.0	26.0	40.0	57.0
	ice						
T.S.S.	open	3	6.0	6.0	3.0	3.0	13.0
	ice						
V.S.S.	open	3	2.0	1.0	1.0	1.0	3.0
	ice						
Total Inorganic Carbon	open	3	115.0	4.0	110.0	117.0	117.0
	ice						
Total Organic Carbon	open	3	53.0	9.0	48.0	48.0	64.0
	ice						
Ammonia Nitrogen	open	3	0.15	0.01	0.14	0.15	0.16
	ice						
Nitrate Nitrogen	open	3	0.01	0.01	0.01	0.01	0.02
	ice						
Ortho Phosphorus	open	3	0.01	0	0.01	0.01	0.01
	ice						
Iron	open	3	0.07	0.01	0.01	0.02	0.19
	ice						
Chlorophyll A mg/m³	open		--	--	--	--	--
	ice						
Manganese	open	3	0.01	0	0.01	0.01	0.01
	ice						

M.R.2

TABLE A5
EMMA LAKE - 1981-82 HEAVY METALS
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - SEASONAL SAMPLES

(Units in mg/L unless noted)

		STATION 1 & 2 (combined)						STATION 3				
		Smpls	Mean	Std. Dev.	Min.	Med.	Max.	Smpls	Mean	Std.Dev.	Min.	Med.	Max
Arsenic ug/L	open	6	1.26	0.56	0.5	1.5	1.8	3	2.36	0.97	1.3	2.6	3.2
	ice	2	1.45	0.35	1.2	1.45	1.7	1	2.1	0	2.1	2.1	2.1
Cadmium	open	6	0.0005	0.00008	0.00049	0.00049	0.0007	3	0.0006	0.0002	0.00049	0.0005	0.001
	ice	2	0.074	0.0063	0.07	0.074	0.079	1	0.051	0	0.051	0.051	0.051
Chromium	open	6	0.003	0.001	0.003	0.003	0.005	3	0.005	0.001	0.004	0.005	0.007
	ice	2	0.115	0.007	0.11	0.115	0.12	1	0.084	0	0.084	0.084	0.084
Cobalt	open	6	0.0009	0	0.0009	0.0009	0.0009	3	0.0012	0.0006	0.0009	0.0009	0.002
	ice	2	0.0019	0	0.0019	0.0019	0.0019	1	0.0019	0	0.0019	0.0019	0.0019
Copper	open	6	0.001	0.002	0.0009	0.0009	0.006	3	0.005	0.004	0.002	0.004	0.01
	ice	2	0.032	0.033	0.009	0.032	0.056	1	0.004	0	0.004	0.004	0.004
Lead	open	6	0.011	0.020	0.0019	0.0019	0.054	3	0.011	0.01	0.002	0.01	0.022
	ice	2	0.01	0	0.019	0.019	0.019	1	0.019	0	0.019	0.019	0.019
Mercury ug/L	open	6	0.049	0	0.049	0.049	0.049	3	0.049	0	0.049	0.049	0.049
	ice	2	0.049	0	0.049	0.049	0.049	1	0.049	0	0.049	0.049	0.049
Nickel	open	6	0.001	0.001	0.0009	0.001	0.005	3	0.006	0.006	0.0009	0.005	0.013
	ice	2	0.05	0	0.05	0.05	0.05	1	0.03	0	0.03	0.03	0.03
Zinc	open	6	0.020	0.035	0.0049	0.0049	0.091	3	0.035	0.043	0.0052	0.016	0.085
	ice	2	0.265	0.063	0.22	0.265	0.031	1	0.91	0	0.91	0.91	0.91

TABLE A5 (Cont'd)
EMMA LAKE - 1981-82 HEAVY METALS
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - SEASONAL SAMPLES

(Units in mg/L unless noted)

Variable		STATION 4 Smpls	Mean	Std.Dev.	Min.	Med.	Max.
Arsenic ug/L	open	3	2.83	1.34	1.3	3.4	3.8
	ice	1	2.1	0	2.1	2.1	2.1
Cadmium	open	3	0.0005	0.0001	0.00049	0.0005	0.0007
	ice	1	0.04	0	0.04	0.04	0.04
Chromium	open	3	0.006	0.002	0.004	0.006	0.009
	ice	1	0.081	0	0.081	0.081	0.081
Cobalt	open	3	0.0019	0.0017	0.0009	0.0009	0.004
	ice	1	0.0019	0	0.0019	0.0019	0.0019
Copper	open	3	0.007	0.010	0.0009	0.002	0.02
	ice	1	0.0019	0	0.0019	0.0019	0.0019
Lead	open	3	0.02	0.023	0.006	0.008	0.048
	ice	1	0.019	0	0.019	0.019	0.019
Mercury ug/L	open	3	0.049	0	0.049	0.049	0.049
	ice	1	0.049	0	0.049	0.049	0.049
Nickel	open	3	0.007	0.002	0.005	0.006	0.01
	ice	1	0.03	0	0.03	0.03	0.03
Zinc	open	3	0.018	0.010	0.007	0.02	0.027
	ice	1	0.044	0	0.44	0.44	0.44

TABLE A6
CHRISTOPHER LAKE - 1981-82 HEAVY METALS
OPEN WATER VS. ICE COVER
UNIVARIATE ANALYSES - SEASONAL SAMPLES

(Units in mg/L unless noted)

STATIONS 1 & 2 (combined)

Variable		Smpls	Mean	Std. Dev.	Min.	Med.	Max.
Arsenic ug/L	open	6	4.08	0.95	2.3	4.4	5.0
	ice	2	4.55	0.35	4.3	4.55	4.8
Cadmium	open	6	0.0009	0.0009	0.00049	0.0006	0.003
	ice	2	0.06	0.08	0.0019	0.0609	0.12
Chromium	open	6	0.006	0.001	0.005	0.006	0.008
	ice	2	0.1	0.11	0.029	0.109	0.19
Cobalt	open	6	0.002	0.002	0.0009	0.0009	0.007
	ice	2	0.0019	0	0.0019	0.0019	0.0019
Copper	open	6	0.005	0.004	0.0009	0.005	0.012
	ice	2	0.0019	0	0.0019	0.0019	0.0019
Lead	open	6	0.022	0.016	0.009	0.014	0.052
	ice	2	0.019	0	0.019	0.019	0.019
Mercury ug/L	open	6	0.049	0	0.049	0.049	0.049
	ice	2	0.049	0	0.049	0.049	0.049
Nickel	open	6	0.014	0.008	0.005	0.012	0.027
	ice	2	0.039	0.043	0.009	0.039	0.07
Zinc	open	6	0.015	0.015	0.002	0.014	0.044
	ice	2	0.4	0.05	0.36	0.4	0.44

TABLE A7

SELECTED CLIMATOLOGICAL DATA - PRINCE ALBERT STATION

DATE	SUNRISE	SUNSET	BRIGHT SUNSHINE HRS.	TEMP C MAX.	TEMP C MIN.	TEMP C MEAN
Aug 1981			302.7 (66%)			
Aug 1-9/81			10.3/d			19.1
Aug 9/81	04:33	19:43	12.1	29.6	10.8	20.2
Aug 10/81	04:35	19:41	13.6	32.0	11.5	21.8
Aug 11/81	04:36	19:39	11.6	27.9	12.3	20.1
Aug 12/81	04:38	19:37	7.3	25.8	8.3	17.1
Oct 1981			76.8 (23%)			
Oct 4-18/81			2.5/d			5.3
Oct 18/81	06:35	17.00	0.3	7.0	-3.2	1.9
Oct 19/81	06:37	16:58	4.4	8.9	-1.0	4.0
Oct 20/81	06:39	16:56	5.2	2.1	-7.1	-2.5
Oct 21/81	06:41	16:54	2.3	-2.1	-7.1	-4.6
May 1982			177.9 (36%)			
May 2-16/82			6.7/d			7.8
May 16/82	04:02	19:56	.0	12.2	6.9	9.6
May 17/82	04:00	19:58	.0	12.5	6.5	9.5
May 18/82	03:59	19:59	.0	13.0	8.4	10.7
May 19/82	03:57	20.01	0.5	13.0	6.5	9.8

Source: Atmospheric Environment Service
Environment Canada, Winnipeg

TABLE A8

EMMA LAKE - FISH TISSUE

HEAVY METAL DATA

Species	Fork Length (cm)	Analyte (ug/g)								
		Arsenic	Cadmium	Cromium	Cobalt	Copper	Nickel	Lead	Zinc	Mercury
Walleye	39.4	0.018	0.015	0.11	0.005	0.53	0.13	<0.05	9.1	0.87
"	40.6	0.019	<0.005	0.062	<0.005	0.42	0.07	<0.05	9.1	0.94
"	40.6	0.016	<0.005	0.13	<0.005	0.39	0.15	<0.05	14	0.85
"	39.4	0.049	0.005	0.11	<0.005	0.47	0.11	<0.05	8.5	0.81
"	41.9	0.019	<0.005	0.087	<0.005	0.35	0.01	0.15	8.8	0.89
"	36.8	0.020	0.005	0.077	<0.005	0.37	0.03	<0.05	11	0.74
"	41.9	0.022	<0.005	0.12	<0.005	0.33	0.03	0.11	13	0.70
"	28.6	0.014	<0.005	0.16	<0.005	0.43	0.13	0.06	8.1	0.52
"*	24.1	0.025	<0.01	0.13	<0.01	0.45	0.13	<0.1	6.6	0.52
"	38.1	0.020	0.010	0.077	<0.005	0.51	0.01	0.06	8.7	0.74
Northern Pike	43.2	0.010	0.010	0.057	<0.005	0.33	0.01	<0.05	8.5	0.52
"	47.0	0.009	0.020	0.057	<0.005	0.26	0.01	<0.05	9.5	0.56
"	59.7	0.007	0.015	0.077	<0.005	0.21	0.01	0.10	9.5	0.88
"	47.0	0.013	0.015	0.062	0.010	0.27	0.01	0.15	12	0.52
"	48.3	0.011	0.005	0.097	0.015	0.56	0.07	0.15	15	0.94
"	47.0	0.010	0.005	0.062	<0.005	0.38	0.03	0.05	13	0.47
"	47.0	0.010	0.010	0.067	<0.005	0.42	0.03	0.10	13	0.59
"	41.9	0.010	0.010	0.26	<0.005	0.39	0.13	0.10	12	0.55
"	42.5	0.008	0.010	0.067	0.010	0.39	0.01	0.05	13	0.41
"	43.2	0.011	0.020	0.087	<0.005	0.42	0.07	<0.05	14	0.63

*Detection limits altered because of small sample.

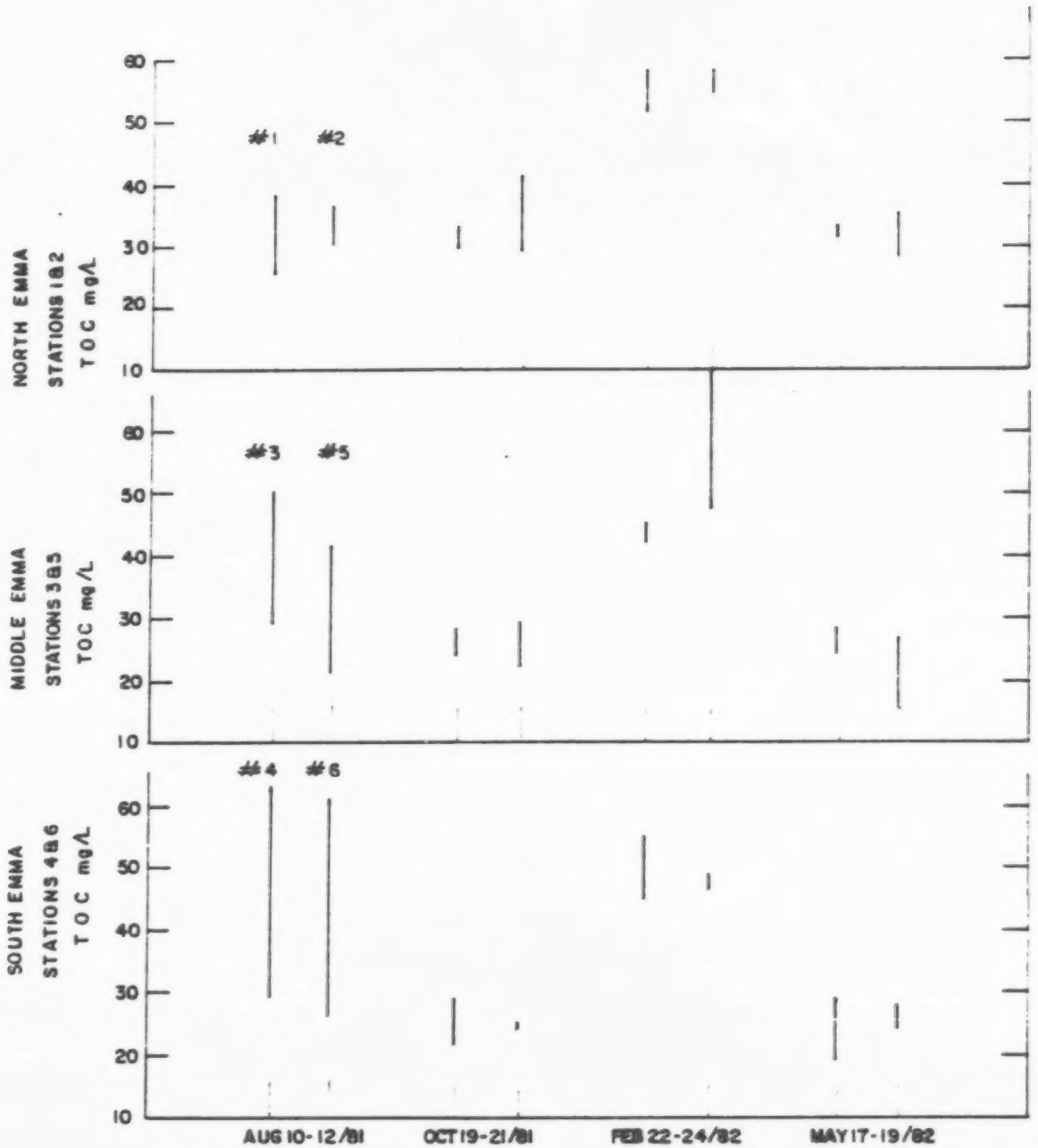
TABLE A9

CHRISTOPHER LAKE - FISH TISSUE

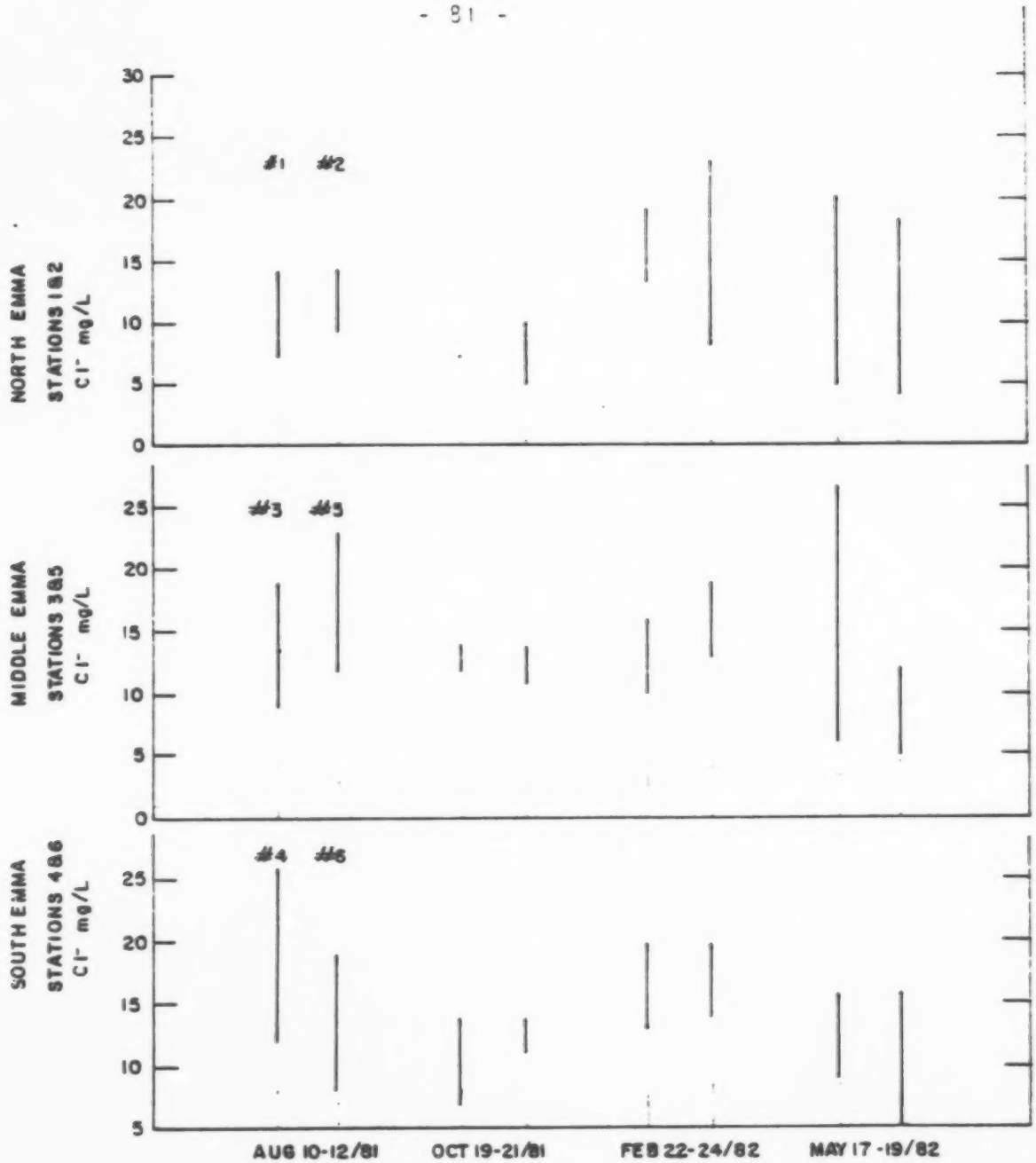
HEAVY METAL DATA

Species	Fork Length (cm)	Analyte (µg/g)								
		Arsenic	Cadmium	Cromium	Cobalt	Copper	Nickel	Lead	Zinc	Mercury
Walleye	44.5	0.010	0.015	0.097	<0.005	0.47	0.09	<0.05	9.5	0.91
"	48.9	0.014	0.005	0.057	0.010	0.43	0.05	<0.05	6.4	1.2
"	48.9	0.016	0.010	0.097	0.010	0.27	0.03	0.05	12	1.2
"	41.9	0.020	0.010	0.087	0.010	0.60	0.09	0.05	9.5	1.3
Northern Pike	85.1	0.014	0.005	0.052	<0.005	0.33	0.27	0.20	6.5	0.95
"	51.4	<0.005	0.010	0.097	0.020	0.44	0.07	0.15	12	0.69
"	58.4	0.019	0.005	0.087	<0.005	0.34	0.05	<0.05	9.4	1.1
"	48.3	0.011	0.005	0.087	<0.005	0.24	0.05	<0.05	14	1.4
"	48.9	0.010	0.015	0.22	0.025	0.38	0.09	0.20	14	1.1
"	54.6	0.005	0.010	0.057	<0.005	0.42	0.05	0.05	7.4	0.78
"	48.3	0.009	0.015	0.052	0.005	0.36	0.01	<0.05	12	0.86
"	53.3	0.009	0.005	0.19	<0.005	0.46	0.09	<0.05	14	1.1
"	54.6	0.020	0.015	0.097	<0.005	0.37	<0.025	<0.05	11	1.4
"	52.1	0.006	0.010	0.14	<0.005	0.37	0.11	0.05	12	1.0

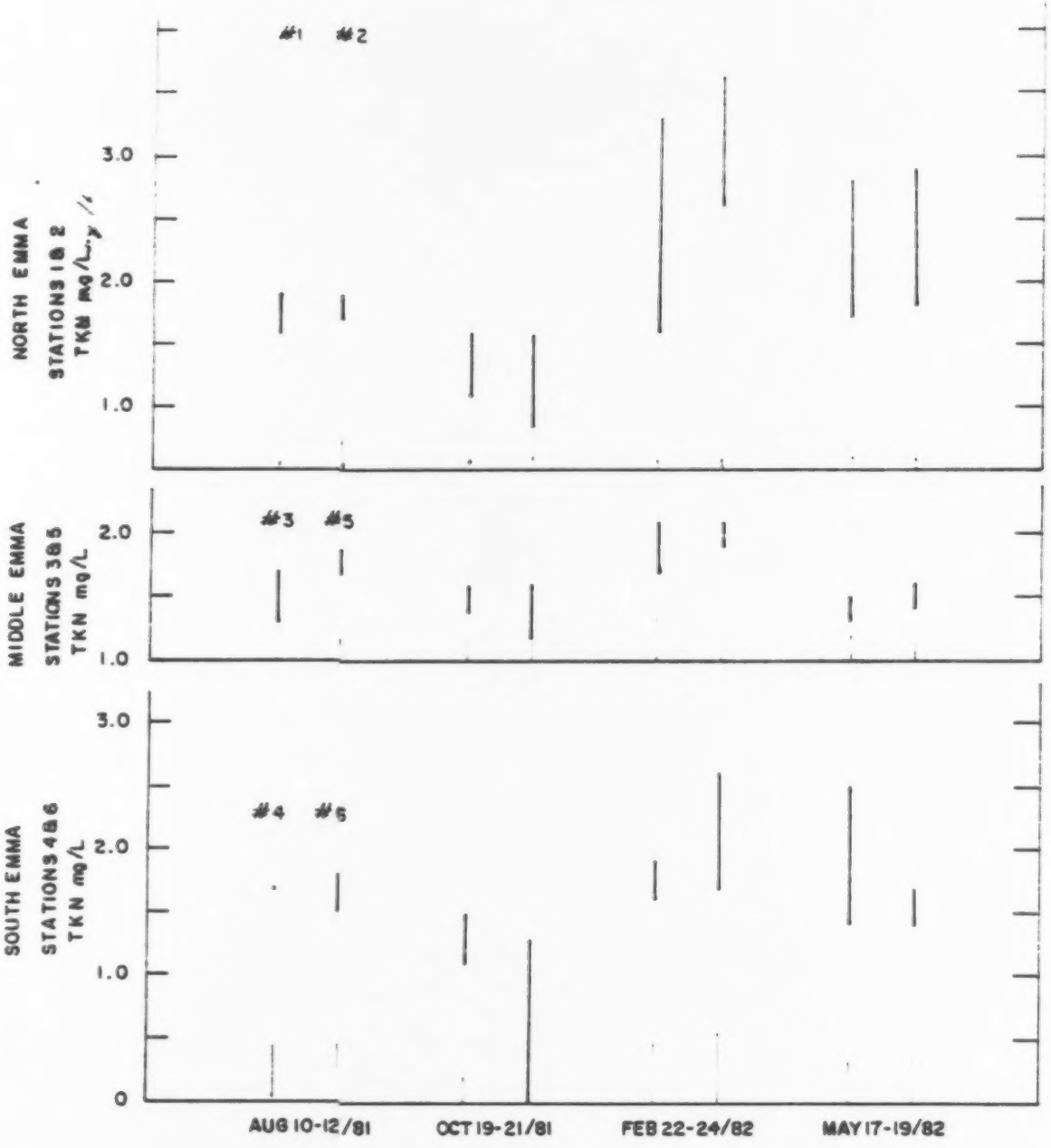
M.R.2



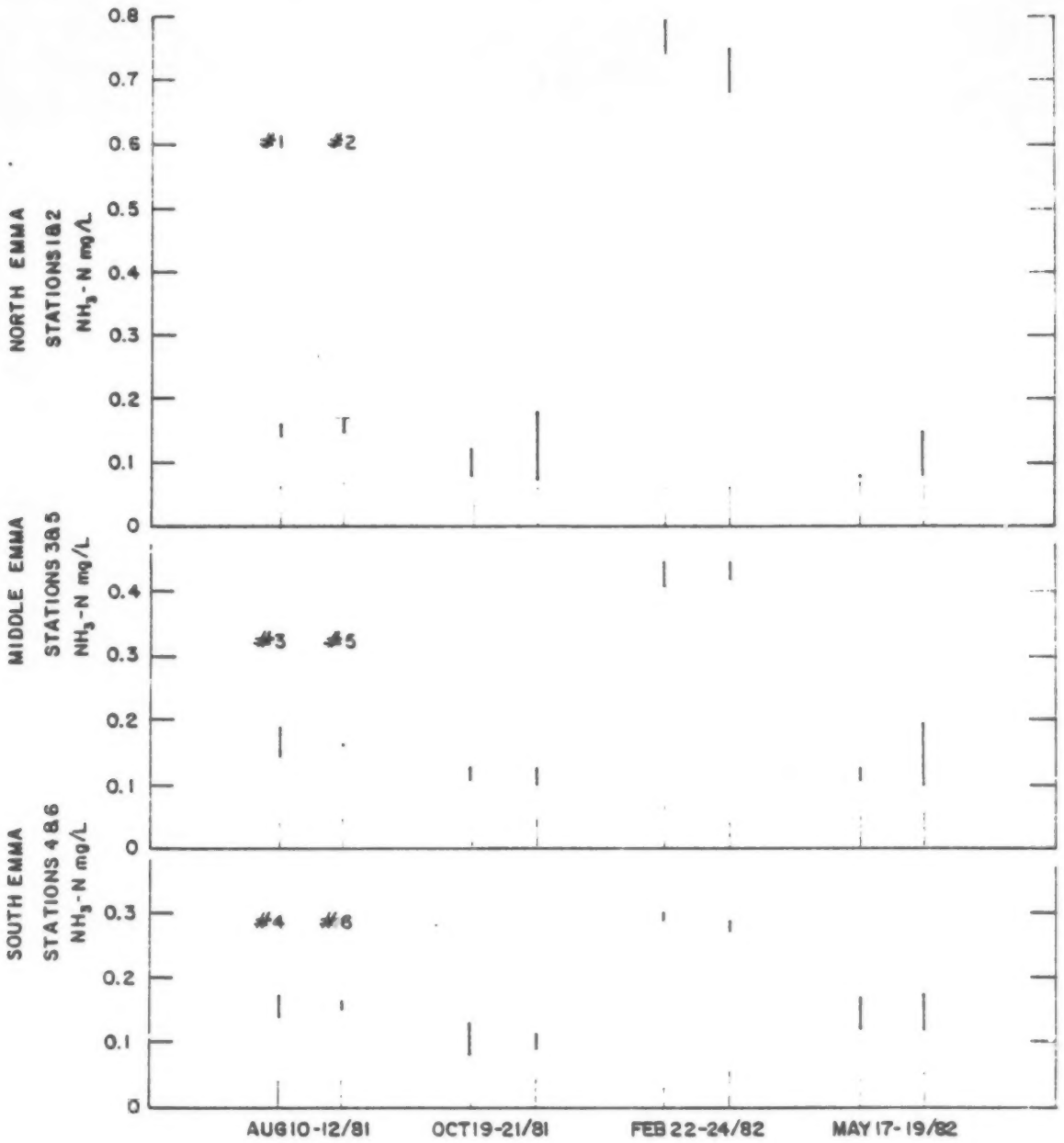
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL ORGANIC CARBON - SEASONAL RANGES - EMMA LAKE		FIG. A-1



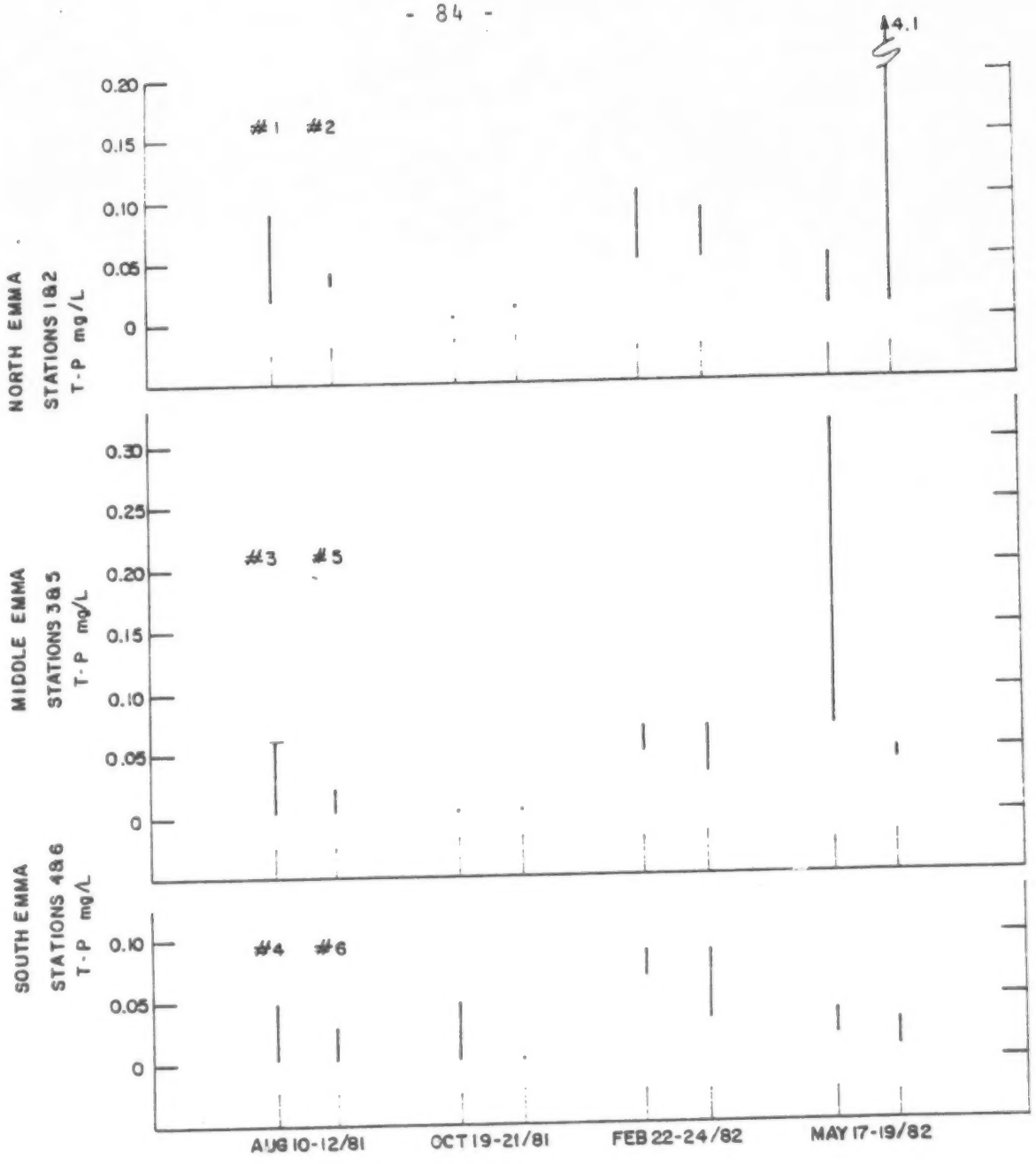
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
CHLORIDE - SEASONAL RANGES - EMMA LAKE		FIG. A-2



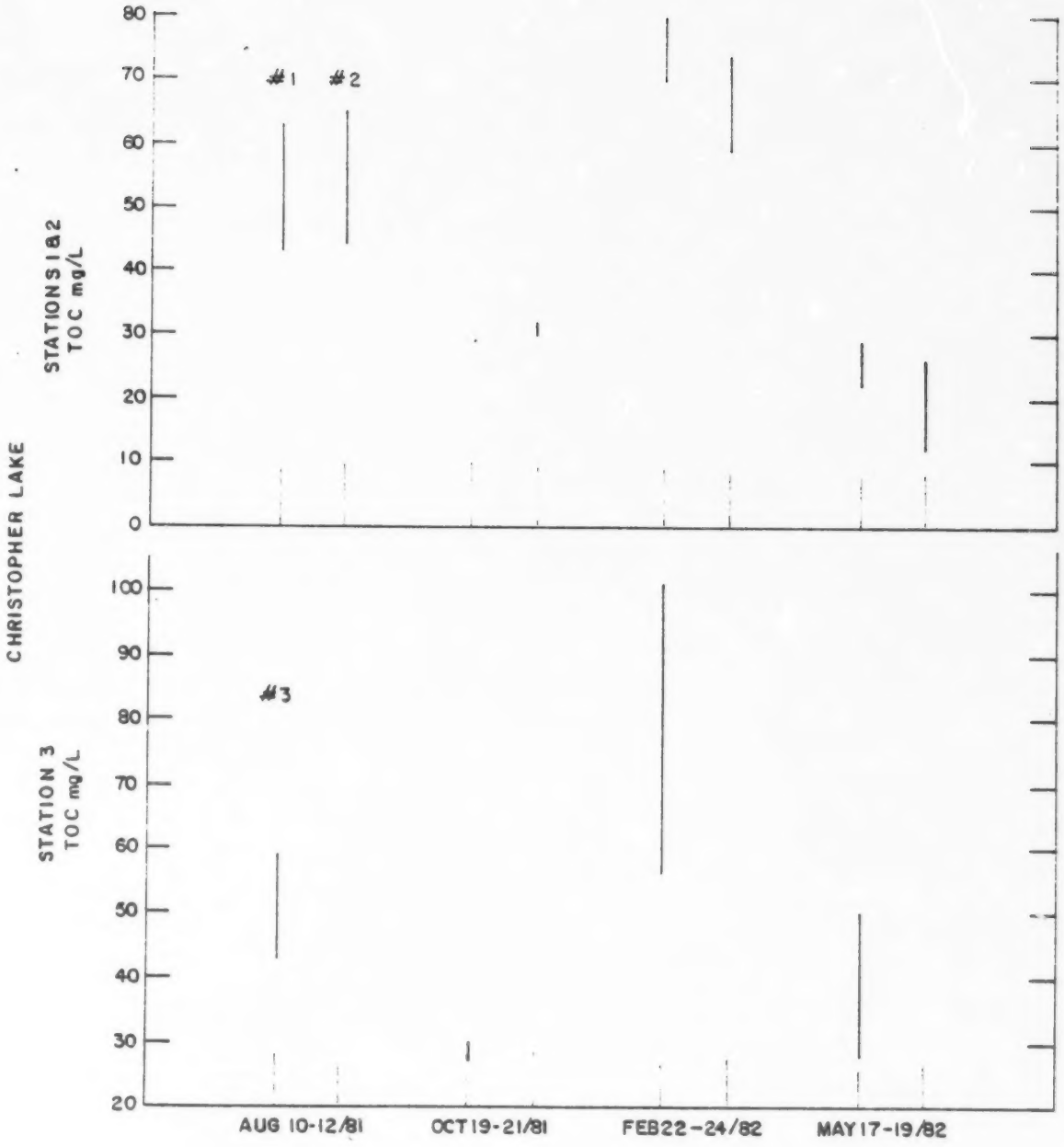
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL KJELDAHL NITROGEN - SEASONAL RANGES - EMMA LAKE		FIG. A-3



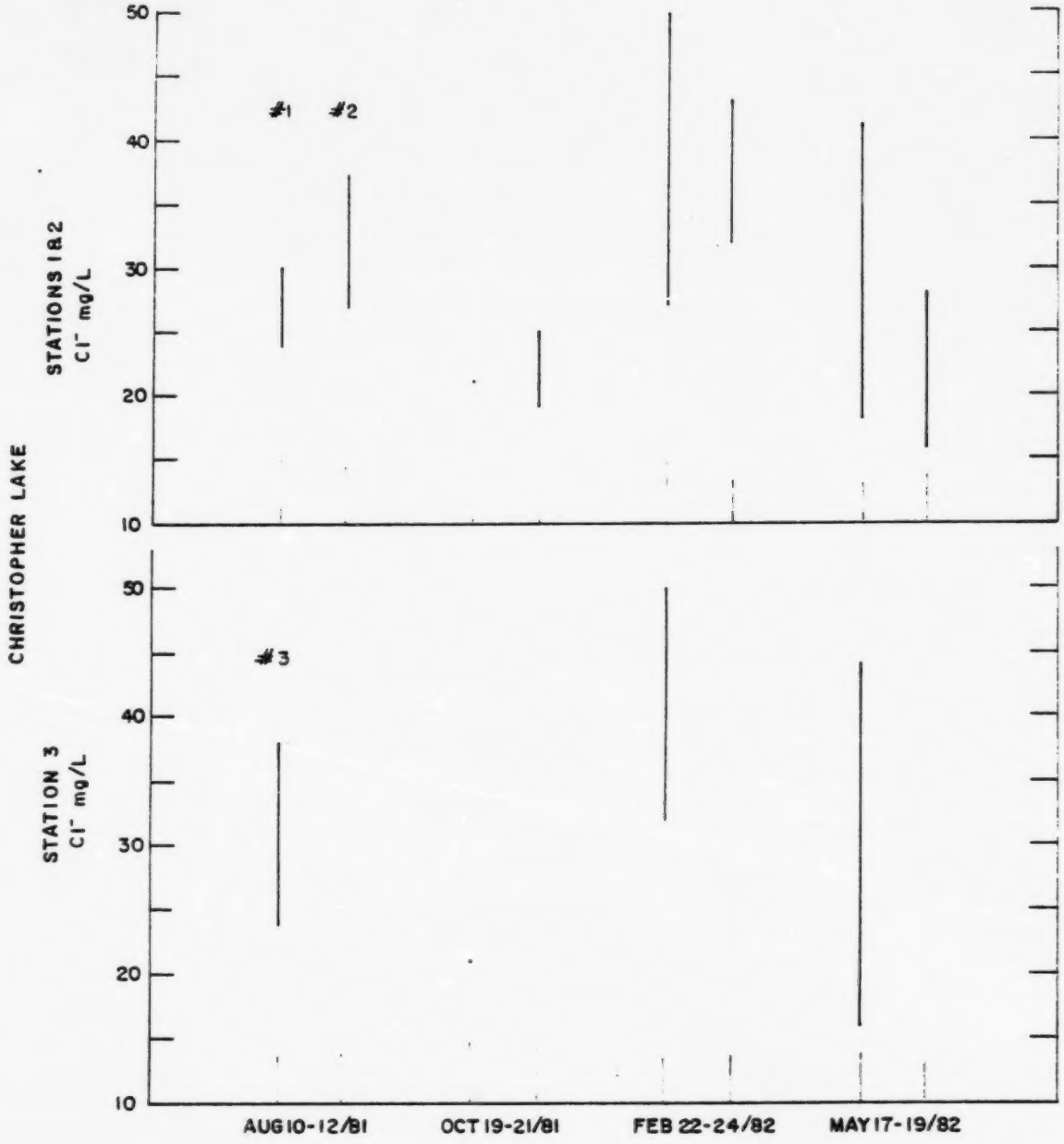
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
AMMONIA-N - SEASONAL RANGES - EMMA LAKE		FIG. A-4



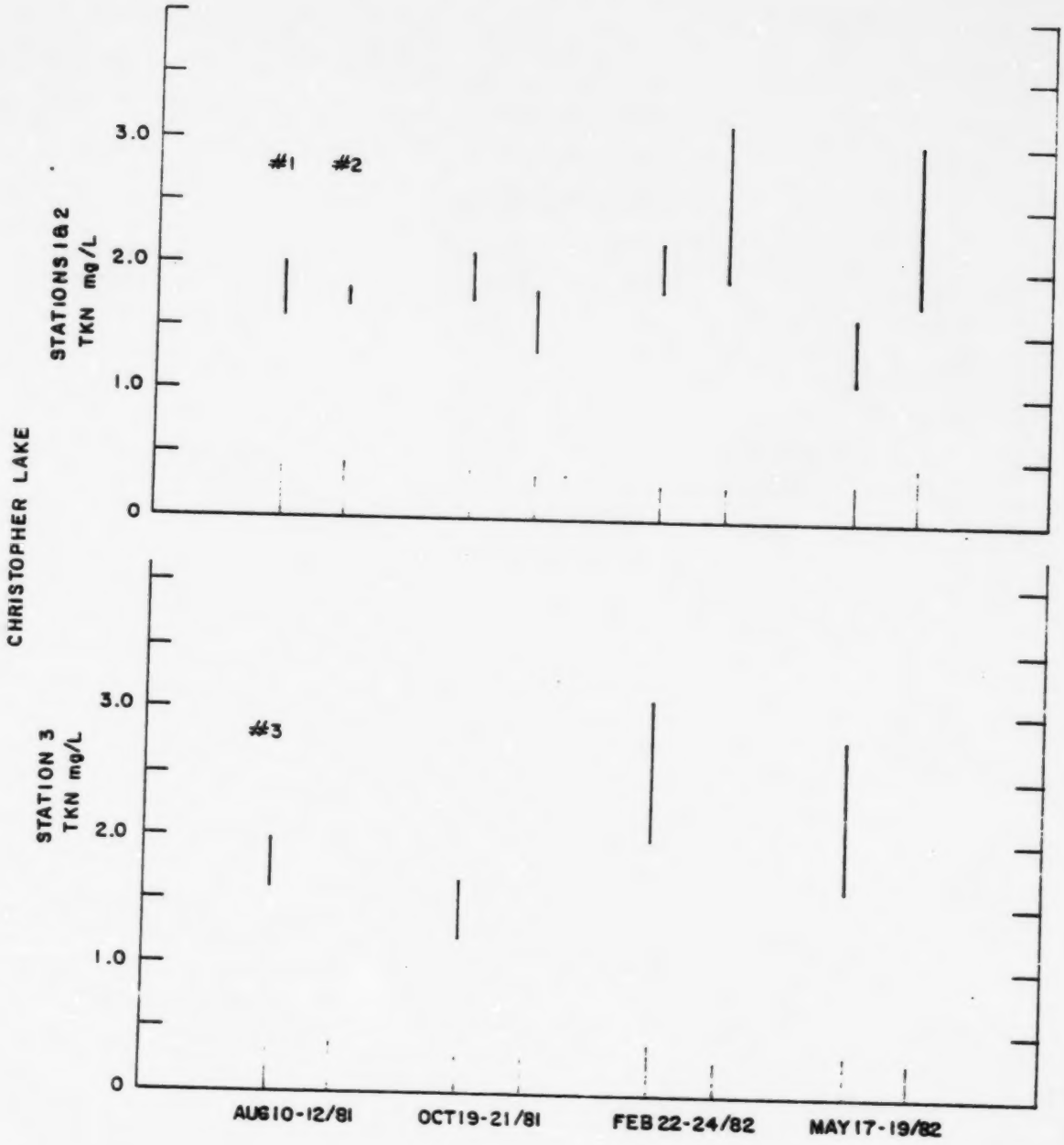
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL PHOSPHORUS - SEASONAL RANGES - EMMA LAKE		FIG. A-5



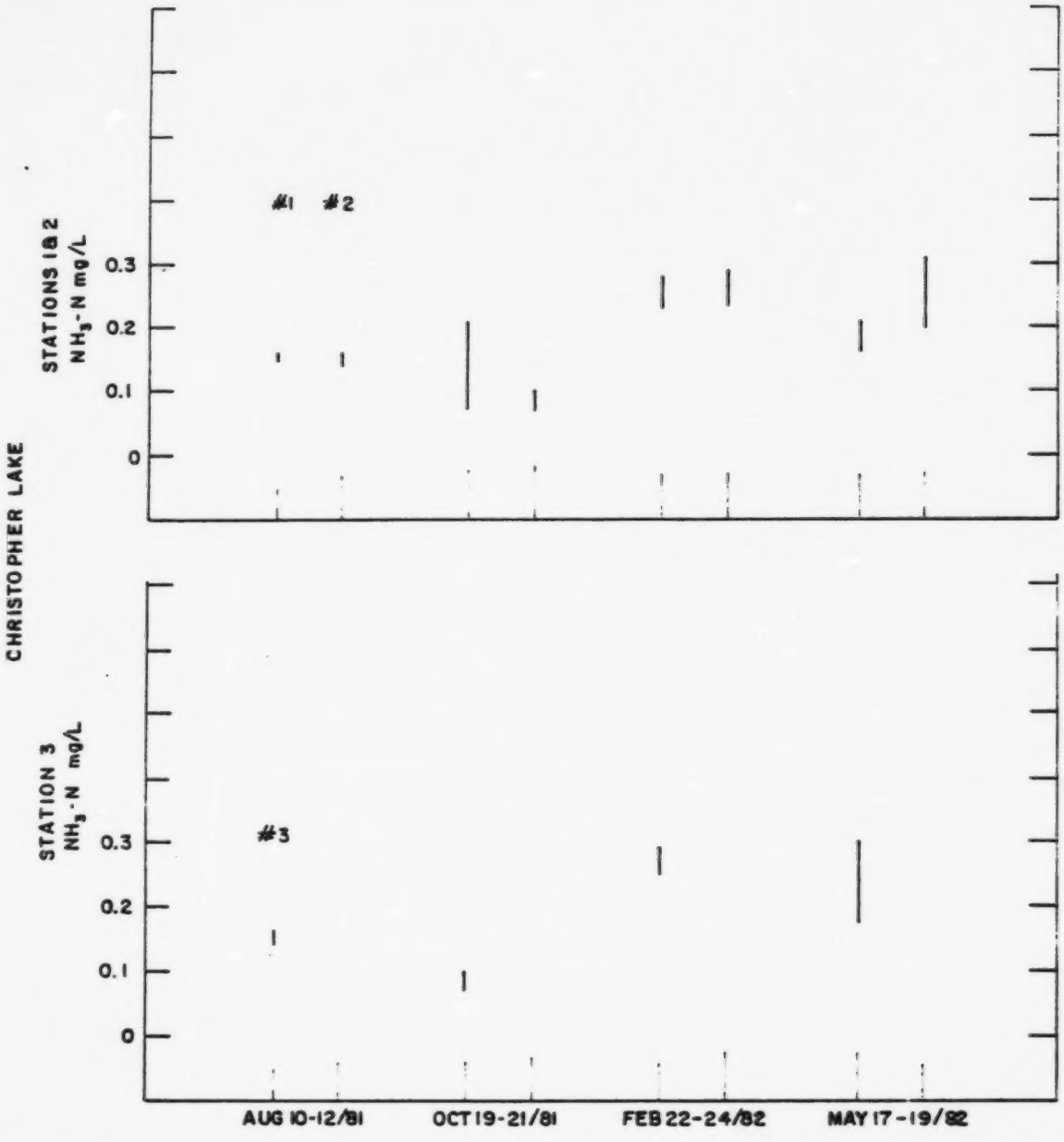
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL ORGANIC CARBON - SEASONAL RANGES - CHRISTOPHER LAKE		FIG. A-6



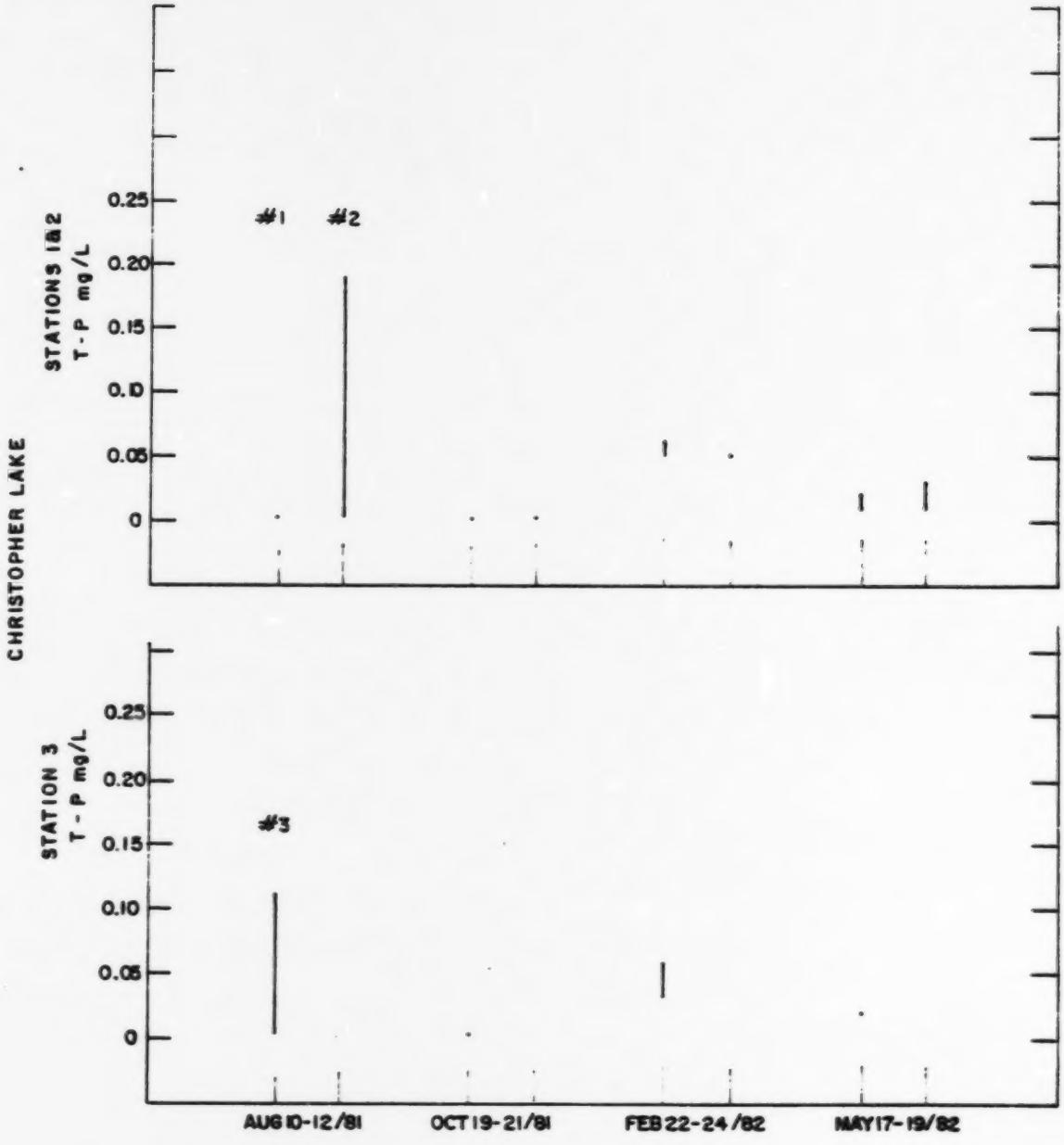
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
CHLORIDE - SEASONAL RANGES - CHRISTOPHER LAKE		FIG. A-7



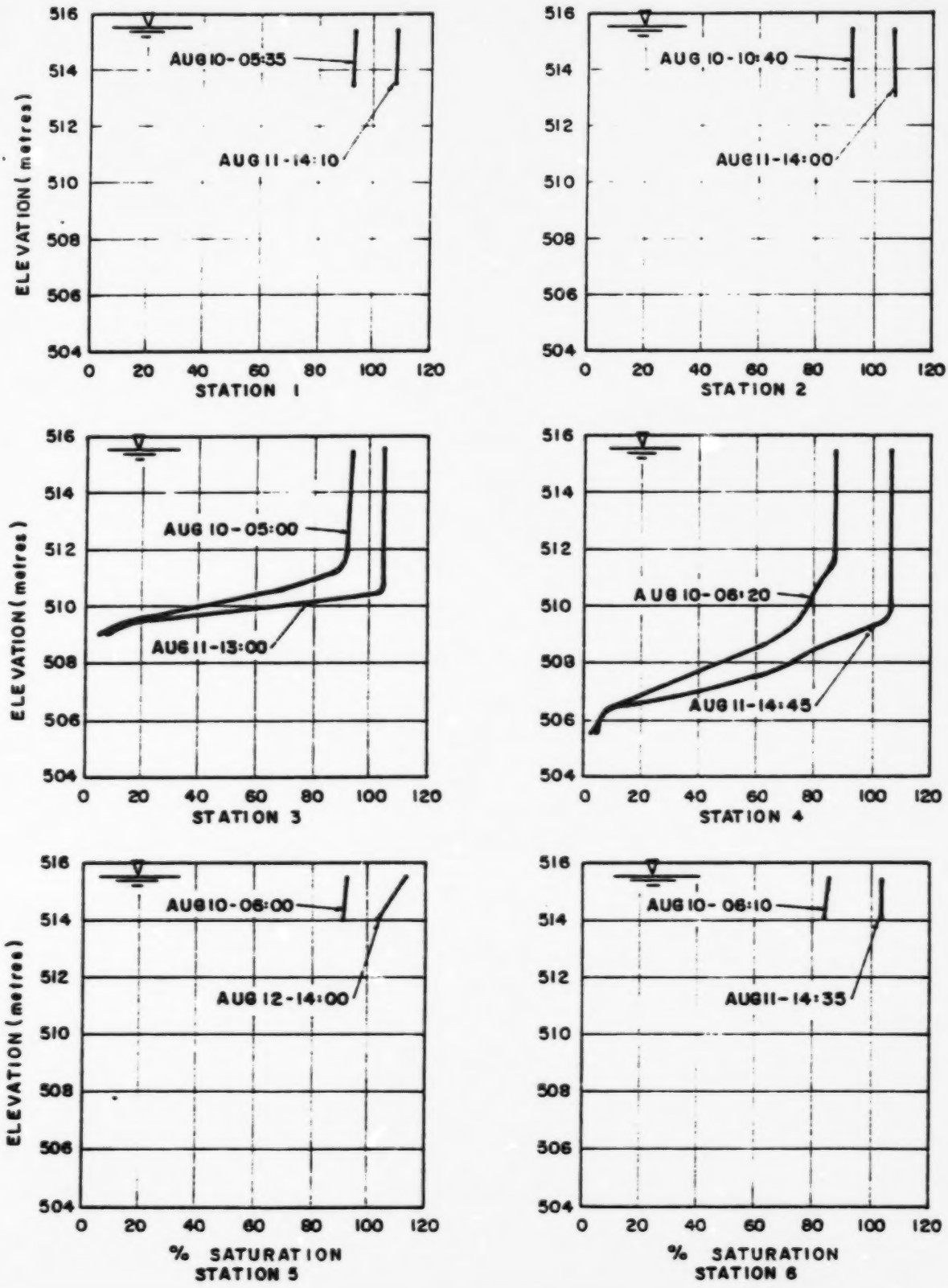
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL KJELDAHL NITROGEN - SEASONAL RANGES - CHRISTOPHER LK.		FIG. A-8



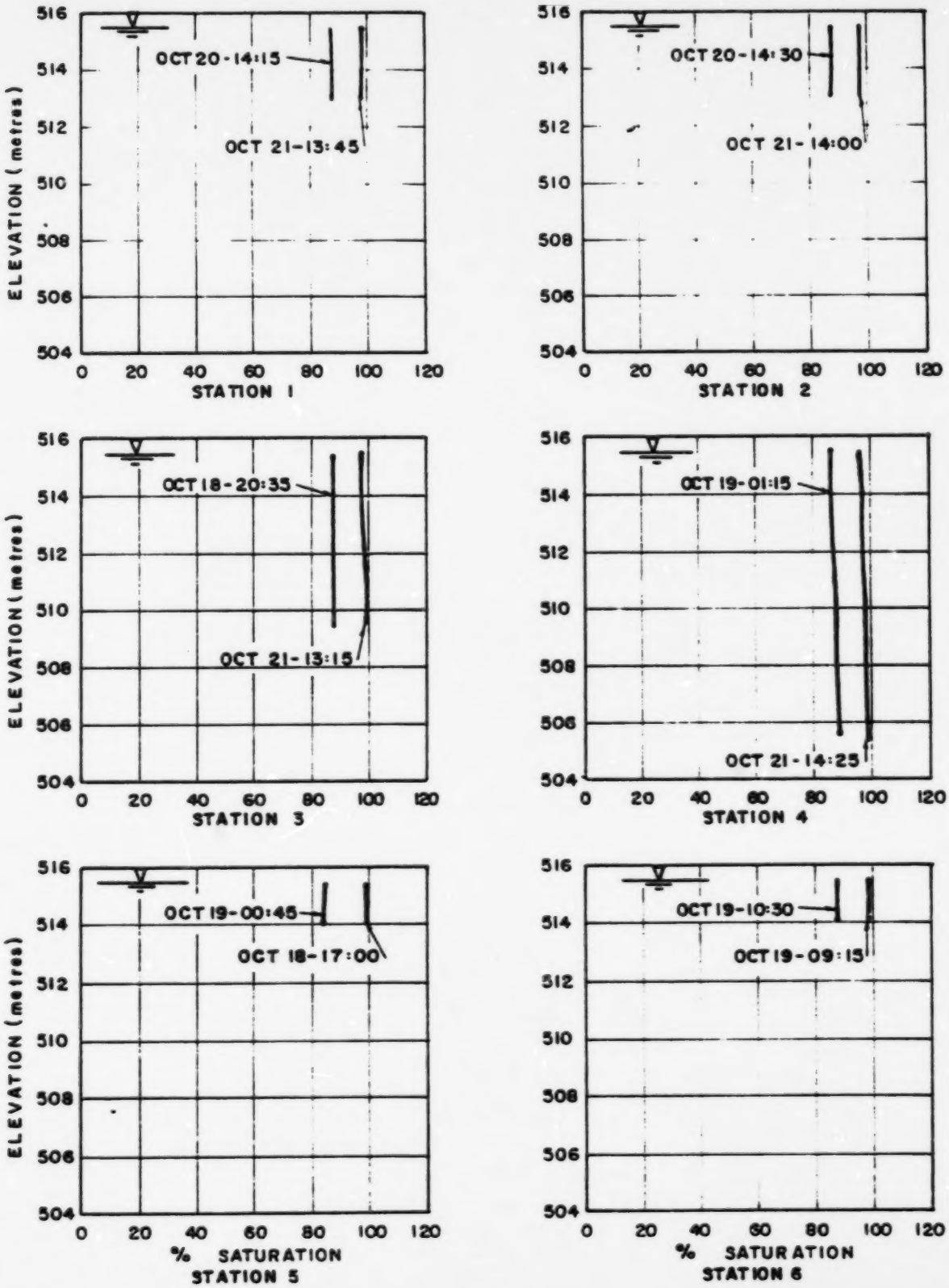
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
AMMONIA-N-SEASONAL RANGES - CHRISTOPHER LAKE		FIG. A-9



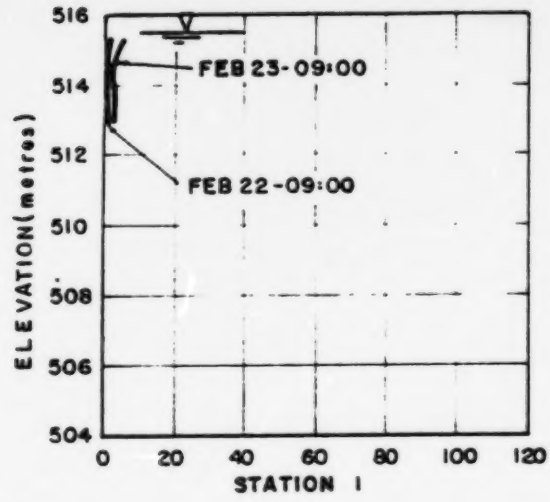
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
TOTAL PHOSPHORUS - SEASONAL RANGES - CHRISTOPHER LAKE		FIG.A-10

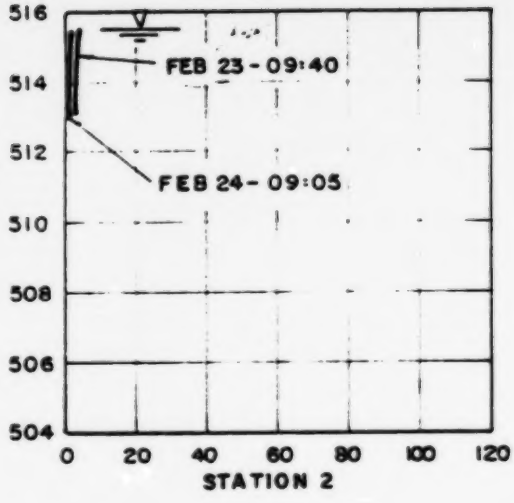


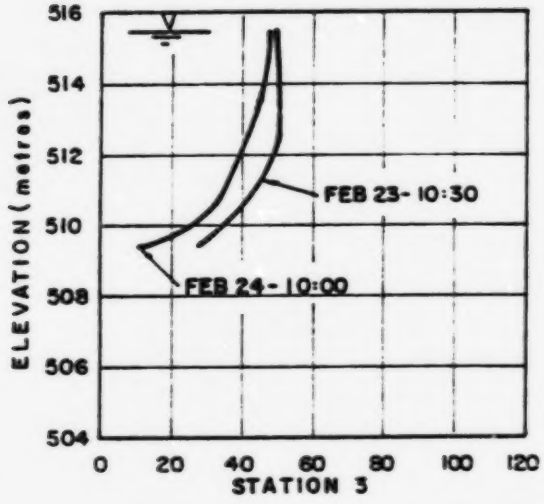
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - EMMA LAKE - AUG/81		FIG. A-11

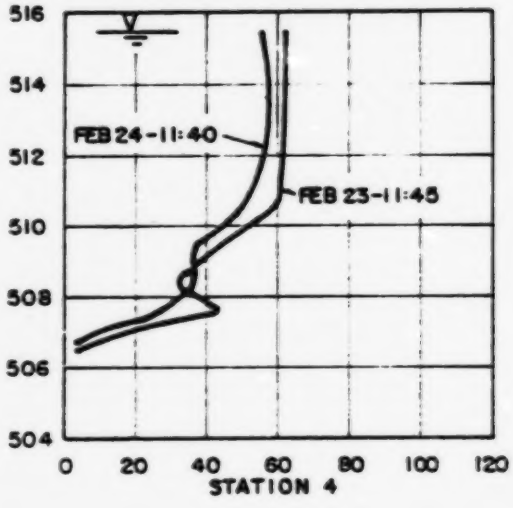


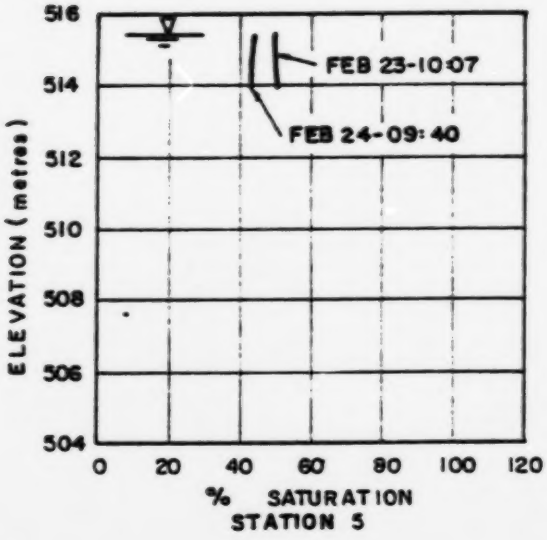
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - EMMA LAKE - OCT/81		FIG. A-12

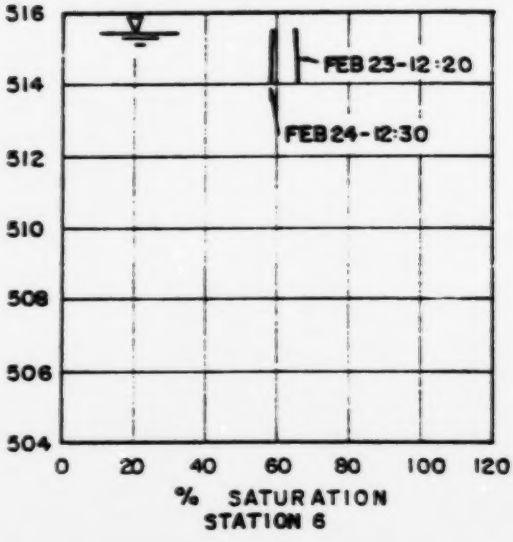




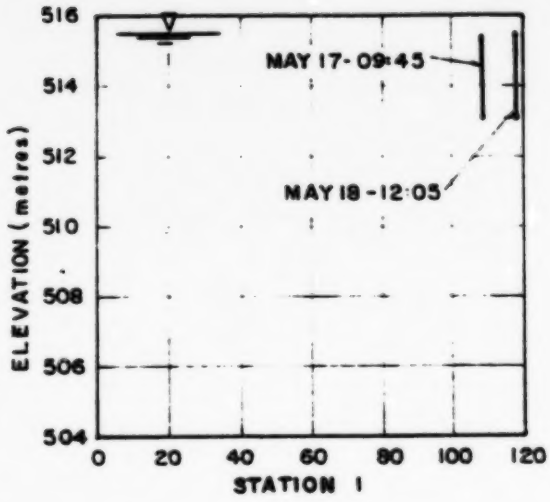


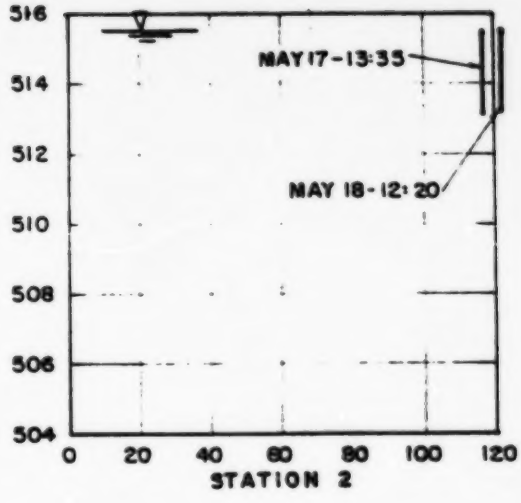


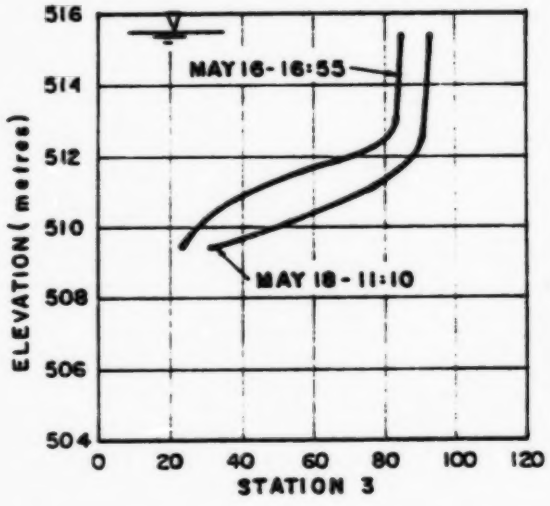


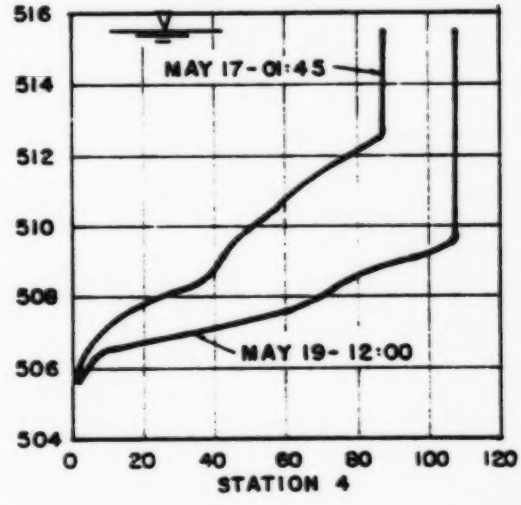


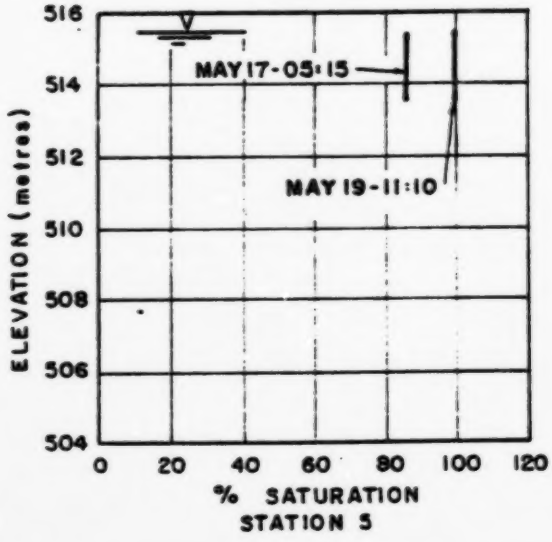
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - EMMA LAKE - FEB/82		FIG. A-13

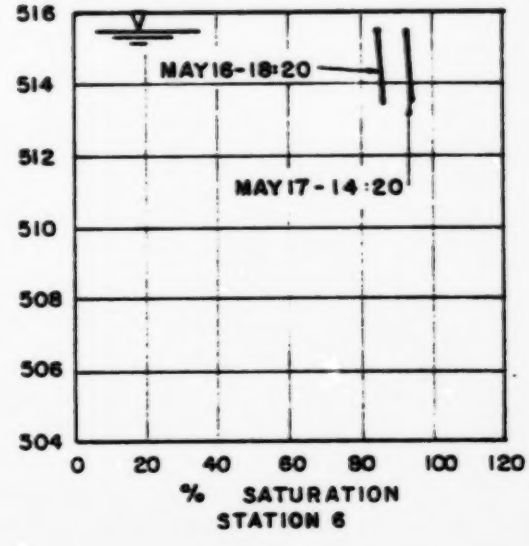




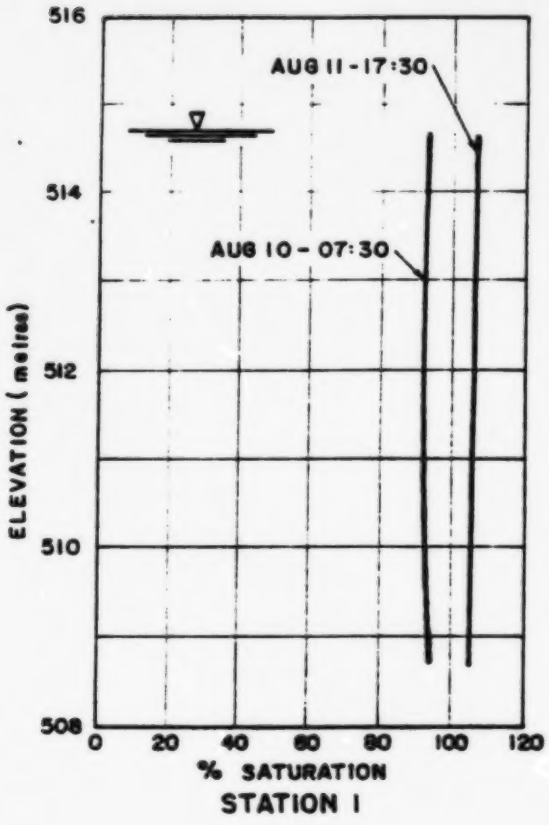


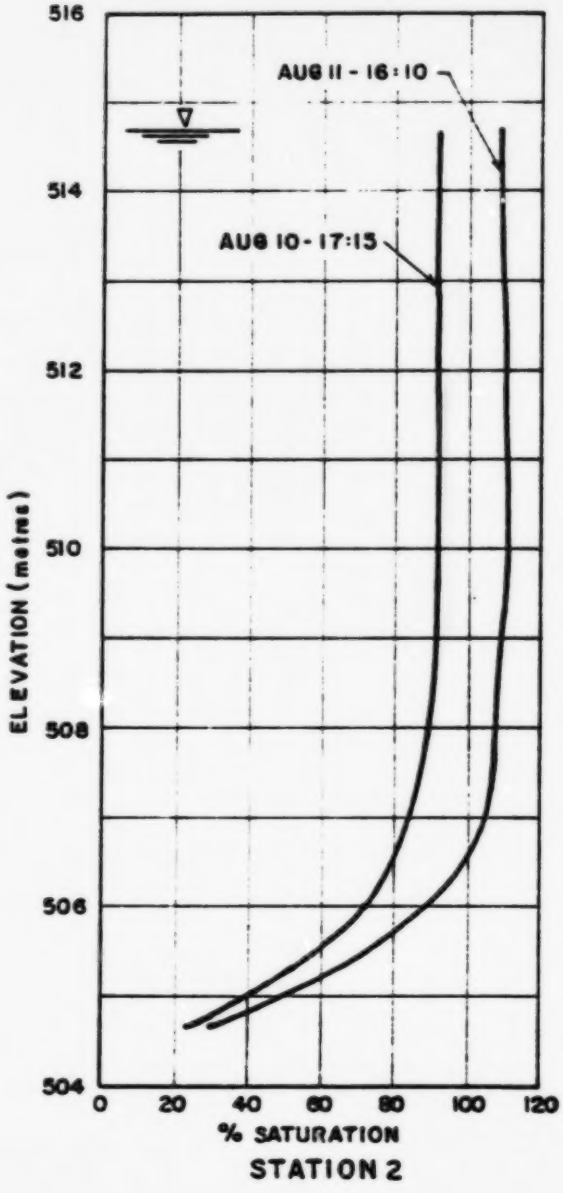


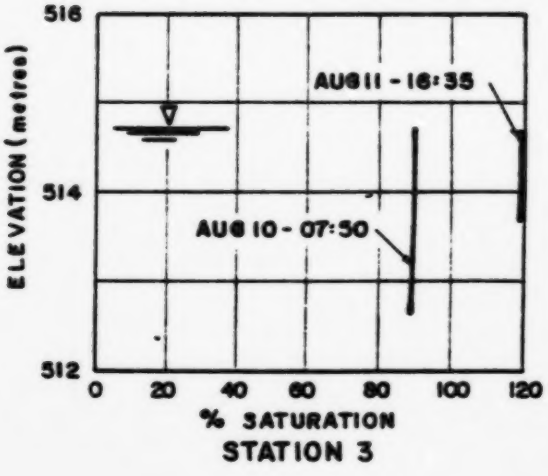




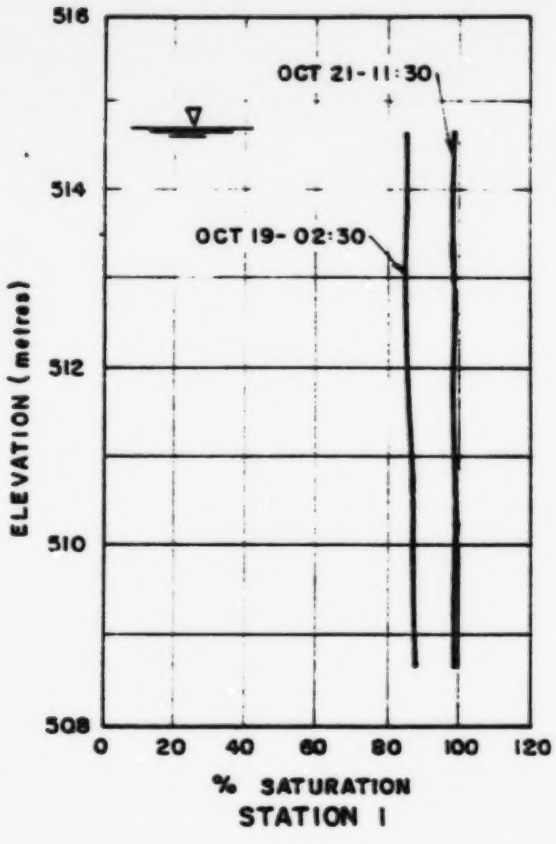
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - EMMA LAKE - MAY/82		FIG. A-14

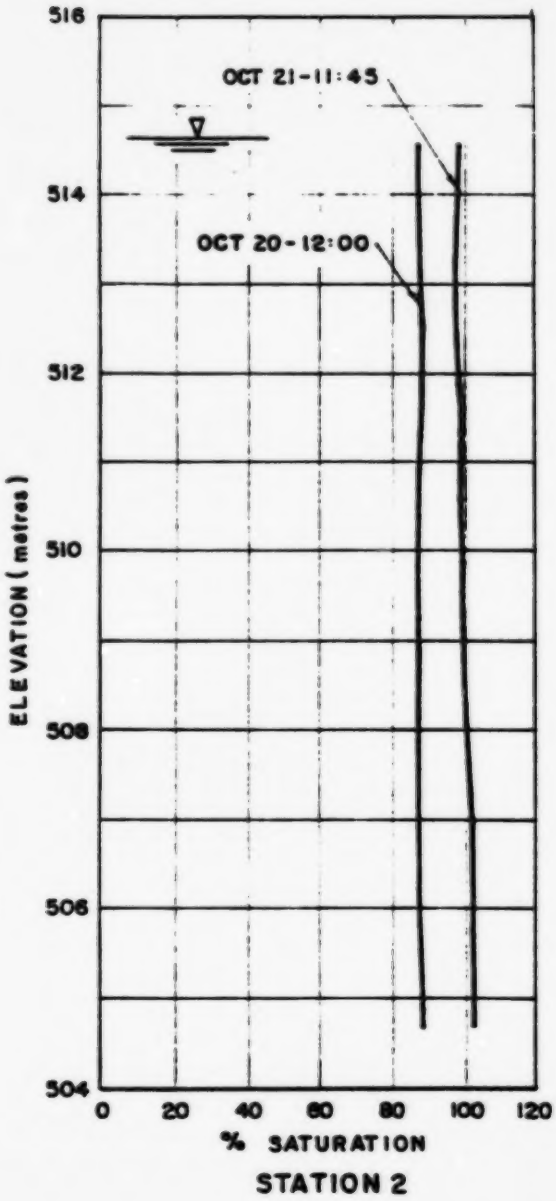


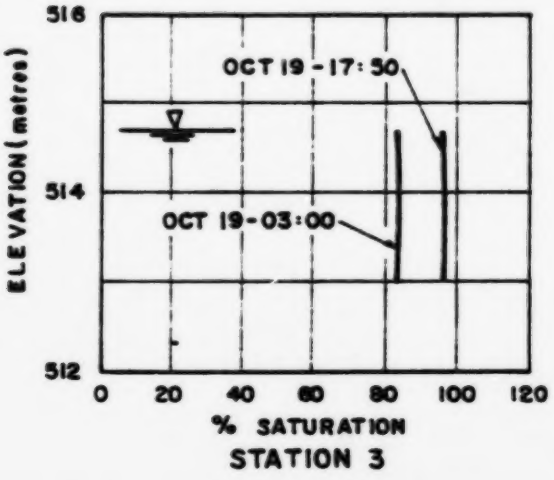




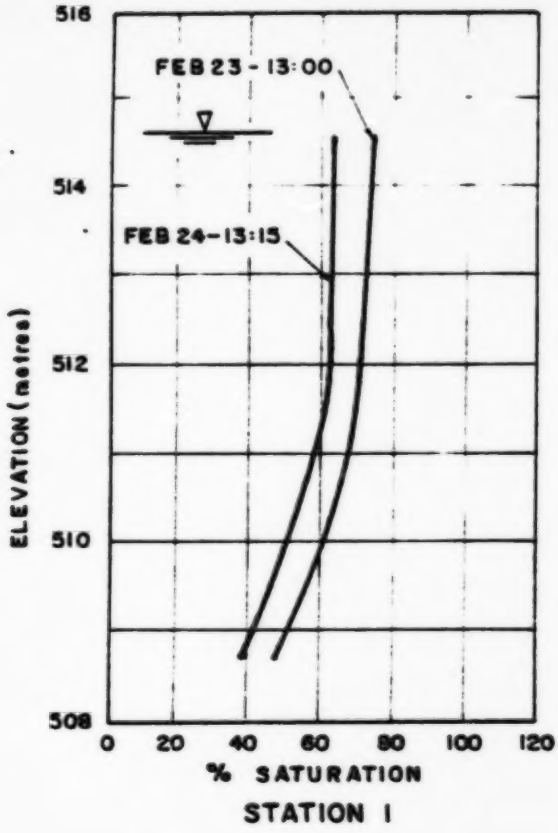
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - CHRISTOPHER LAKE - AUG/81		FIG. A-15

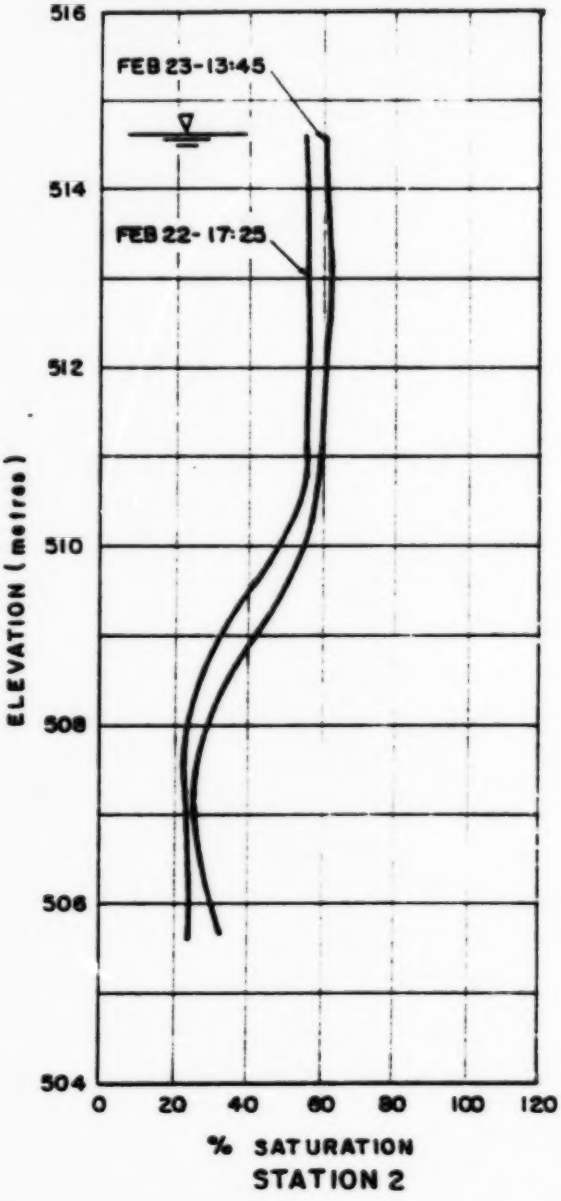


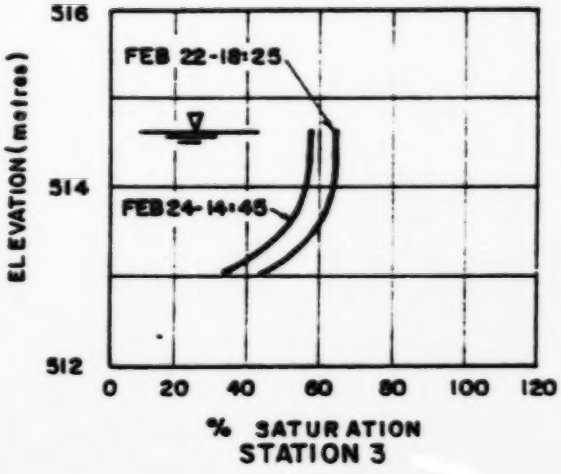




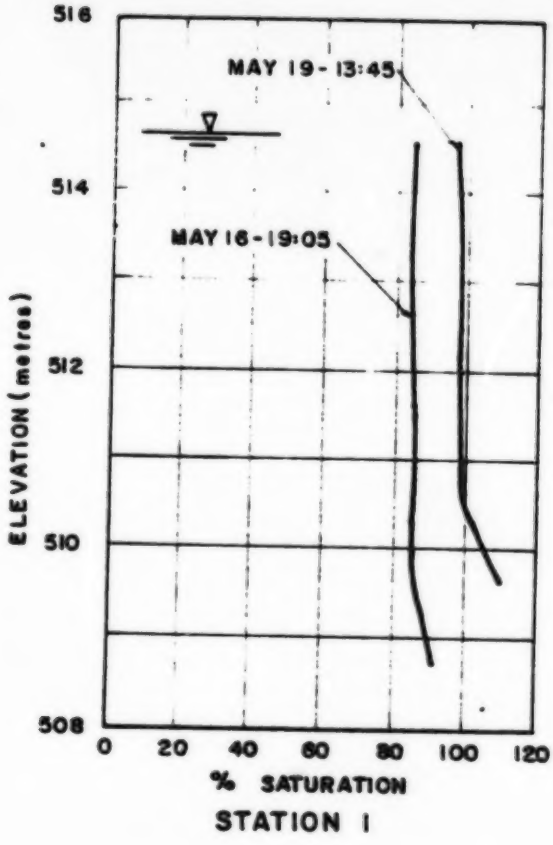
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - CHRISTOPHER LAKE - OCT/81		FIG. A-16



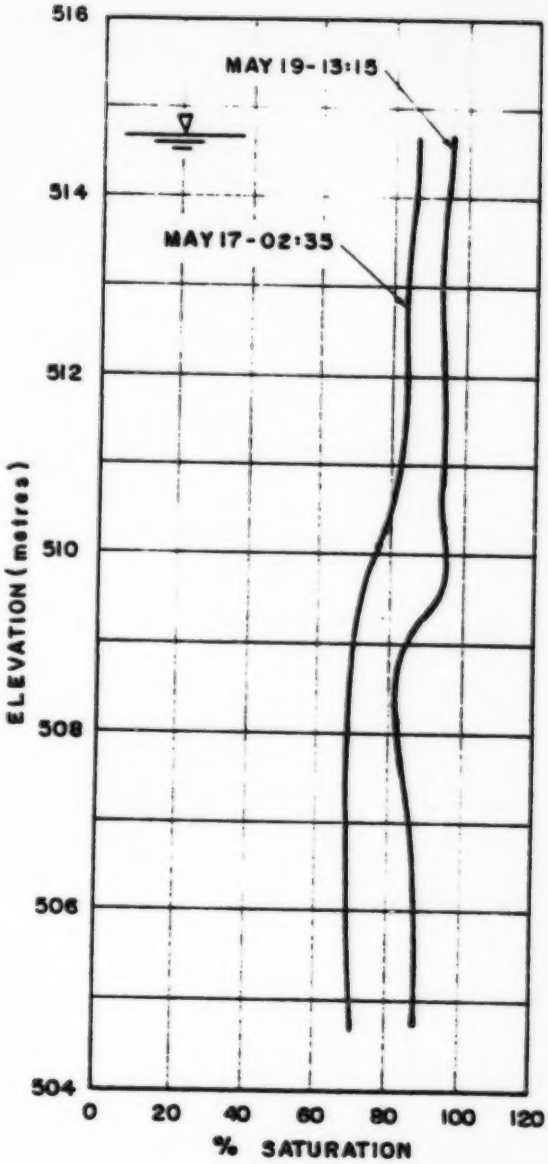




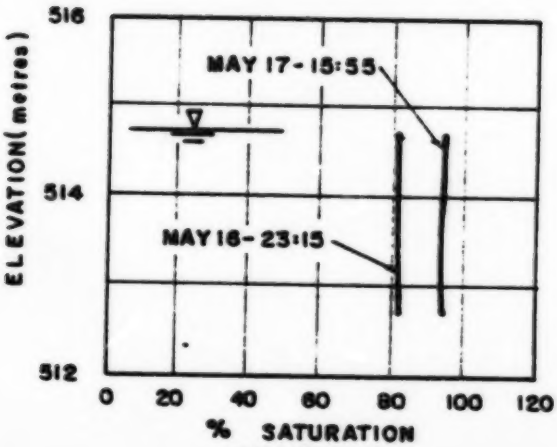
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES-CHRISTOPHER LAKE - FEB/82		FIG. A-17



STATION 1

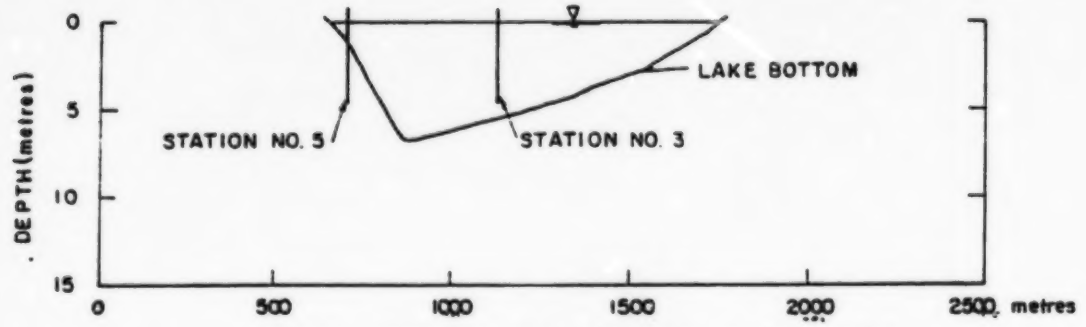


STATION 2

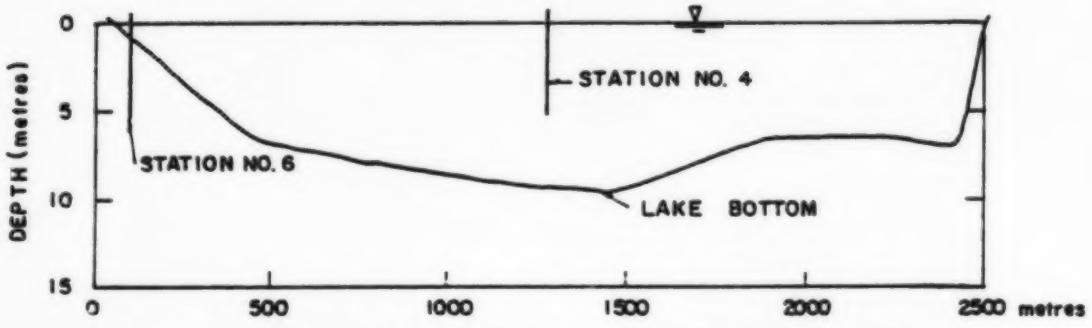


STATION 3

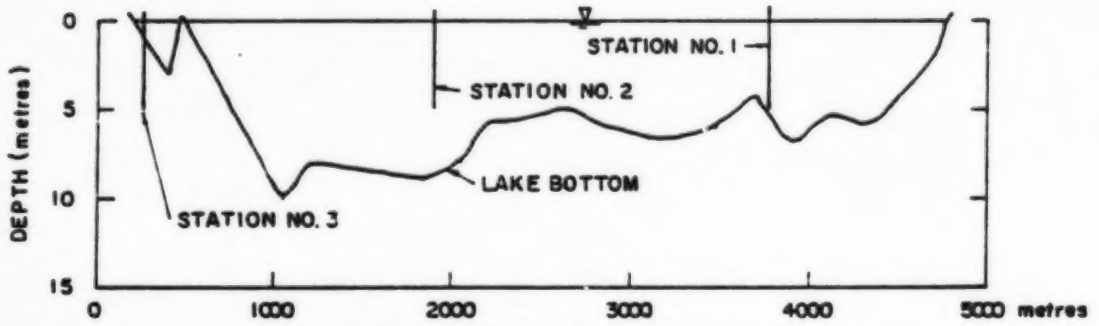
M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
DISSOLVED OXYGEN PROFILES - CHRISTOPHER LAKE - MAY/82		FIG. A-18



CROSS SECTION A-A - MIDDLE EMMA LAKE



CROSS SECTION B-B - SOUTH EMMA LAKE



CROSS SECTION C-C - CHRISTOPHER LAKE

REFER TO FIG. 2-1 FOR SECTION LOCATIONS

M·R·2 CONSULTING ENGINEERS	EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	DATE MARCH/83
	SELECTED CROSS SECTIONS	FIG. A-19

LEGEND

- EMERGENT VEGETATION
- FISH COLLECTIONS
- WINTER DO < 0.5 mg/L
- BLUE GREEN ALGAE
- GREEN ALGAE
- DIATAMS

PREDOMINANT SPECIES AUG/81

M·R·2 CONSULTING ENGINEERS	
EMMA AND CHRISTOPHER LAKES 1981-82 WATER QUALITY ASSESSMENT	
MISC. BIOLOGICAL INFORMATION	DATE MARCH/83
	FIG A20

POOR

QUALITY

ORIGINAL